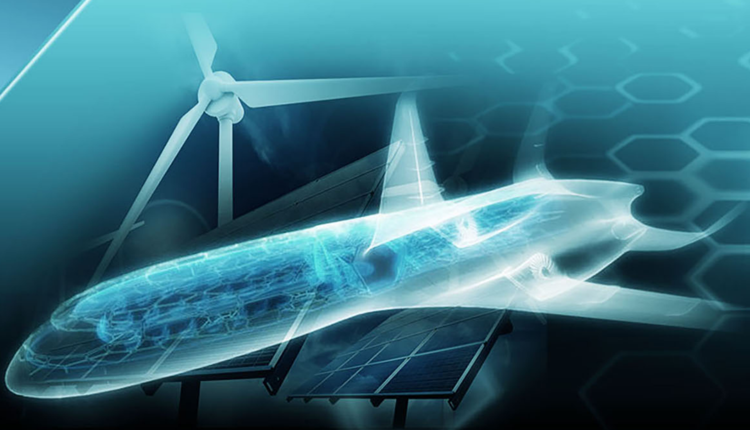

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Introduction

Chronic stress is called as «silent killer» of the 21st century. Ignoring the signals and delaying the problem until last can lead to numerous deaths or disabilities. To guarantee a person's ability to work in such conditions, it is necessary to ensure the functional reliability of all body systems, stability and reserve capabilities of the body. Optimization of rational nutrition in extreme conditions with special food products for these conditions (biologically complete and balanced in terms of basic food products) is a problem for scientists in this field of activity.

This task can be solved in two ways. The first consists in studying and constantly monitoring the state of health of people in conditions of constant stress, as well as correcting their condition due to the use of food rations based on special culinary products. This approach requires the creation of a system for collecting information, forecasting the state of a person under conditions of constant stress for several periods ahead and long-term work of experts. The result requires significant financial costs and is achieved after a long period of time. However, it allows you to comprehensively study this issue in perspective, find a way out and protect yourself from risks.

Under the influence of chronic stress, the central nervous system becomes vulnerable, which can cause alcohol and drug abuse, malnutrition, overeating, or lead to behavioral changes and social withdrawal. Stress can make things difficult if you have breathing problems like asthma or emphysema. Responding to stress, a person, trying to distribute a lot of oxygen and blood throughout the body, breathes faster. The heart works faster under stress. The blood vessels constrict and, in order to provide the strength for an urgent reaction, direct more oxygen to the muscles. This helps to increase blood pressure. Persistent hypertension increases the risk of stroke and heart attack. In turn, this causes pain throughout the body, because chronic stress keeps the

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muscles in constant tension. In stress the liver produces extra sugar (glucose) to provide us with energy. But sometimes body may not be able to cope with the increased level of glucose if this condition turns into a chronic one. This increases the risk of developing type II diabetes.

Smart-technologies of food products for people in conditions of constant stress, which use dietary plant additives, were scientifically grounded and developed on the basis of theoretical and experimental studies. A scientific concept and possible concepts of its realization are proposed. Optimizing the nutritional composition of special food products for people in conditions of constant stress must be carried out according to the algorithm proposed in the project, which makes it possible to obtain a new food product with specified properties. The task of optimizing product recipes consists in the scientifically based selection of functional ingredients and their ratios, which ensure the maximum approximation of the mass fractions of food substances to personalized norms. Principles of nutrition for people in conditions of constant stress are systematized and nutrient groups to keep them main organism systems active are defined. Biological value of composite dietary plant additives is calculated. Criteria for optimization of food product nutrient compositions which use dietary plant additives are grounded. The model of ensuring the activity of the main body systems of people in conditions of constant stress is proposed. Innovative idea of using plant-based natural complexes in food products for the people in conditions of constant stress are worked out.

Products rich in potassium, zinc, copper, iodine, and selenium, i.e. dietary stress protectors, prolong life and inhibit the spread of stress in society. Ensuring the daily need for chelated metals by the developed diet determines the prevention of oncological pathologies, as well as the antisclerotic, lipotropic, antioxidant orientation of the diet.

1.1. Background

The «silent killer» of the 21st century is called chronic stress, ignoring signals and postponing the problem until the last, sent by the human body, which leads to numerous deaths or disabilities. To ensure a person's ability to work in such conditions, it is necessary to ensure the functional reliability of all body systems, stability and reserve capabilities of the body. Optimization of the diet in extreme conditions due to special food products for these conditions (biologically complete and balanced products in terms of basic nutrients) is an urgent task for scientists in this field of activity.

The central nervous system (CNS) becomes vulnerable under the influence of chronic stress, which can cause overeating, malnutrition, abuse of alcohol, drugs or lead to changes in behavior, social withdrawal. Responding to stress, a person, trying to spread oxygenated blood around the body, accelerates breathing. Stress can make things worse if you have breathing problems such as asthma or emphysema. Under stress, the heart starts to work faster. Blood vessels narrow to give strength for an urgent reaction, to send more oxygen to the muscles. This helps to increase blood pressure. Persistent hypertension increases the risk of stroke and heart attack. In turn, this causes pain throughout the body, because chronic stress keeps the muscles in constant tension. During times of stress, the liver produces extra sugar (glucose) to provide us with energy. But the body may not cope with the increased level of glucose if this condition becomes chronic. This increases the risk of developing type II diabetes [1–2]. A special place in the formation of pathological manifestations and disruption of physiological processes in humans belongs to environmental factors. Stress is a non-specific neuroendocrine component of the mobilizing reaction of the entire body to any given demand (stressor). Stressors:

1) irritants that really threaten homeostasis (for example, pain, hypoxia, hunger, antigenic aggression);

2) the stimuli are unexpected or such as violate the stereotype;

3) stimuli that are potentially dangerous (based on previous experience [1, 3– 4].

Stress as a neuroendocrine process was first described in 1936 by the Canadian pathophysiologist G. Selye [4]. Stressors of various origins lead to numerous metabolic disorders, which are known as "adaptation diseases". According to modern ideas, the viability of an organism in an emergency situation is higher, the better the cells of vital organs tolerate hypoxia. This applies to all types of homeostasis, reproductive function, differentiation, immunity, growth and development of both humans and animals. At the current stage of the development of medical and biological sciences, an urgent problem is the study of the chelation of metals in cells under the influence of stressful and pathogenic factors and physiological stimuli on the body, as well as the general patterns of changes in cellular metabolism. Study of the nature of cellular reactions to stressors from the point of view of factors, studies of the role of copper, magnesium and zinc, which are involved in many metabolic processes. There is more zinc in the cells of the human and animal body than all other trace elements, besides, zinc ranks 27th among other metals in the earth's crust. Specifically it’s participates in gene of transcription, differentiation, growth and development of organisms, reproduction, immune reactions, is part of the active center of proteins (more than 300 enzymes). Their participation in the mechanisms of the general adaptive cellular syndrome and other adaptive processes helps to study the nature of changes in metalloligand homeostasis under the influence of stressors. There are two different pools of metals in human and animal bodies. The first pool is tightly bound to bioligands, it is contained in all cells of the body and is not determined by staining with chelators-chromophores. The first pool affects the stability of biomembranes and is part of most metalloenzymes. The second pool is weakly bound to bioligands, and the term "chelatable" metal is increasingly used for it. This refers to a weakly bound metal, which is detected in cells with the help of chelators-chromophores [5–6].

At this stage, the body is not yet saturated with hormones of the adrenal glands, so the adaptive restructuring of the metabolism is not complete and the resistance to acute hypoxia is not yet increased. At this stage, the body begins to produce stress-regulatory hormones of the adenohypophysis [7].

At the "stage of resistance" a general adaptation syndrome (GAS) is formed. The body is saturated with glucocorticoids and other corticosteroid hormones, as well as

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catecholamines. The body is saturated with glucocorticoids and other corticosteroid hormones, as well as catecholamines. As a result of the acute counterinsular effect of stress hormones on metabolism, the acceleration of oxygen and energy substrate transport is ensured, as well as the redistribution of energy resources in favor of organs and tissues (CNS, myocardium, respiratory muscle of the diaphragm, adrenal glands). themselves, gonads), retina, etc.), which contain insulin-independent glucose transporters, glycogenolysis and gluconeogenesis are mobilized.

All this has an anti-shock effect characteristic of stress during acute hypoxia. But lymphoid organs, connective tissue, musculoskeletal system, lipocytes, gastrointestinal tract, vascular wall, etc. are temporarily in a state of energy deprivation. With strong and prolonged stressful actions, the functional resources of the neuroendocrine apparatus may be exceeded. In this case, the stress may reach the "exhaustion stage" (including passing the "resistance stage"). The increased non-specific resistance characteristic of ACS is lost or not formed [7, 9].

Stress that has led to the stage of exhaustion is called "distress". Distress is a risk factor for many diseases ("diseases of impaired adaptation" - atherosclerosis, hypertension, secondary immunodeficiency, obesity, osteochondrosis, arthritis, and many others), which damage organs and tissues and are manifested by stress in conditions of energy deprivation. Antidotes used to bind and remove toxic and radioactive metals from the body are chelators. Compounds with pronounced chelating properties can be formed in the body itself as a result of deep metabolic disorders, questions are increasingly being raised about the possible role of these substances in the development of various diseases, such as diabetes, schizophrenia, epilepsy, Parkinson's and Alzheimer's diseases, etc. Many medicinal substances can bind metals in chelated forms: antimicrobial, antitumor, psychotropic agents.

One of the most important problems of modern physiology and medicine is the study of the regularities of the process of adaptation of the organism to various environmental factors. Under the action of stress of various genesis, the processes of non-specific adaptation syndrome are triggered. The biological essence of any adaptation of the body is formed at the cellular level.

It is known that during the action of adverse factors on the body, general changes develop in the cells of many tissues and organs, which can be characterized as a non-specific adaptation syndrome of the cellular system (NASCS). The data available in the literature indicate the need to study the relationship between zinc and copper, because antagonistic relationships between these metals are possible in the mechanisms of development of NASCS [9, 10].

First of all, human adaptation affects a wide range of general biological laws, so the interests of workers in various scientific fields are related to the self-regulation of multicomponent functional systems. To assess the process of adaptation of athletes, the degree of their fatigue, the level of training and work capacity, it is necessary to determine the functional changes that occur during loads, and is the basis for improving recovery measures. Only on the basis of a comprehensive analysis of the set of reactions of the entire organism, including reactions from the central nervous system, hormonal apparatus, cardiovascular and respiratory systems, analyzers, metabolism, etc.

It is possible to judge the impact of physical and psychological stress on a person. The expressiveness of changes in body functions in response to physical exertion depends primarily on the individual characteristics of a person and the level of his training and stress resistance. Only when considering changes in the functional indicators of the human body relative to the adaptation process can they be correctly analyzed and comprehensively evaluated [2,11]. In the last decade, the problem of stress has become increasingly relevant in various fields of medicine. Despite numerous fundamental and applied studies in this field, the issues of combating the negative consequences of stress remain the most acute and the least resolved. The need to reduce the manifestations of stress, based on its signaling value, remains debatable. Stress, with which the body reacts to an extreme influence that poses a threat to a person's physical existence or his mental status, is a special functional state (FS). Stress occurs as a complex reaction of the body with the involvement of biochemical, humoral, vegetative, behavioral, emotional and other mental processes [12 14]. In this work, we will adhere to the definition of stress as "... the functional state of the body, which arises as a result of an external negative influence on its mental functions, nervous processes or the activity of peripheral organs" [6, 9]. Adaptation is a biological function of stress, the purpose of which is to protect the body from various threatening, destructive influences (physical or mental). A person "engages" in a certain type of activity aimed at resisting the dangerous effects of the environment, which indicates the occurrence of stress. As stress develops, the body's physical activity and reactions change. This type of activity corresponds to a special FS and a complex of various physiological reactions. Stress is associated with a chain of reactions that begin with the production of adrenocorticotropic hormone (ACTH) by the pituitary gland. This is how stress is described in the neuroendocrine theory of the occurrence and regulation of stress. Through the cortex of the large hemispheres, the stressor signals the hypothalamus that danger has arisen. The mobilization of norepinephrine (NA) occurs in the neurons of the hypothalamus, which begins to activate the noradrenergic elements of the limbicoreticular system and causes the excitation of the centers of the sympathetic nervous system, which in turn enhances the activity of the sympatho-adrenal system and leads to the release of a mixture of adrenaline and NA from the medulla of the adrenal glands into the blood. This process enriches the blood by 80-90% with adrenaline and 10-20% with noradrenaline. Stress hormone (ACTH) does not limit its action to stimulation of corticosteroidogenesis. During an acute response of the body to damage, this hormone exhibits extraadrenal effects that are essential for restructuring the metabolism and physiological functions of organs under stress and are independent of corticosteroids [15–18]: ACTH has a delayed insulinotropic effect on the islet of Langerhans, which indirectly affects the exchange of chelating metals and strengthens metabolic changes during stress turn to the anabolic phase [19]. The hypothalamus is responsible for controlling homeostasis set points. Physiologically, this part of the diencephalon regulates heat transfer and heat production, appetite and satiety, thirst and diuresis, induction of opposite changes in blood pressure [20–22]. At the same time, the content of chelating metals can also change, but these issues have not been investigated, although all these indicators change dramatically under stress [23–24]. According to the principle of compensation for deviations of metabolic constants from set points, the main controlling effects of the hypothalamus on metabolism are carried out due to the coordinated response of the endocrine and autonomic nervous system [25]. There is every reason to believe that the hypothalamus is the main element of the limbic system, which coordinates biologically appropriate behavior, determines what is pleasant and desirable, and what is unpleasant and disgusting for an individual, in his feelings and behavioral reactions [22, 26-28]. It is here that a lot of chelated zinc accumulates, and the affective component of sensations and reactions in the limbic system is formed. In turn, the hippocampus makes it possible to manage stress reactions in response to various sensory stimuli [27–29]. Reorganization of metabolism and physiological functions, which dramatically increases the survival and resistance of the organism to acute death in extreme conditions, is caused by stress (Fig. 1).

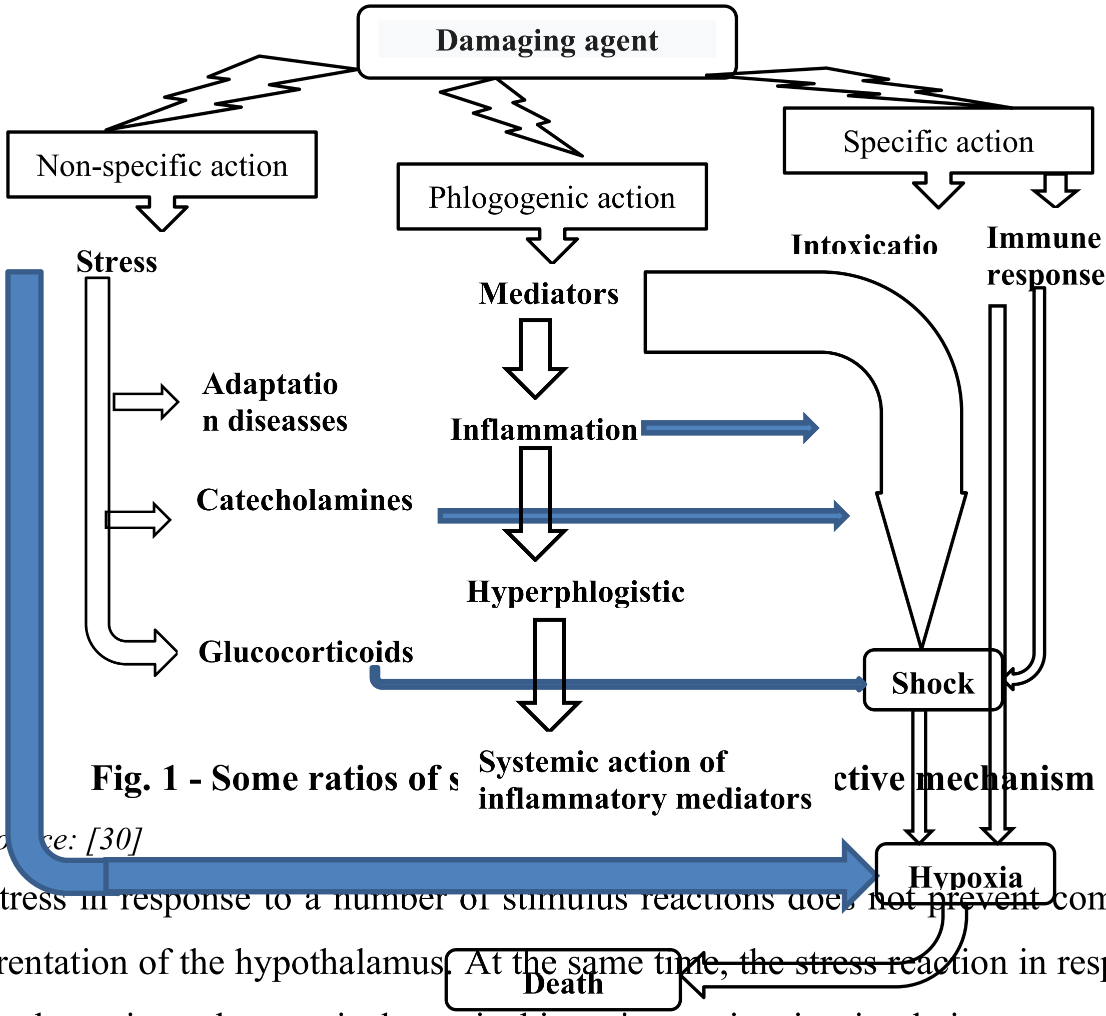

Fig. 1 - Some ratios of s... ctive mechanism

Source: [30]

Stress in response to a number of stimulus reactions does not prevent complete deafferentation of the hypothalamus. At the same time, the stress reaction in response to hypoglycemia, endotoxemia, hypoxia, histamine, antigenic stimulation, serotonin is reproduced without changes, the reaction to overheating is partially preserved [21–22].

The dependence of the energy metabolism of cells in different organs and tissues on insulin is not the same. First of all, this applies to carbohydrate metabolism. Glucose entry into different cells of the body is regulated by different carriers. Only some of the carrier proteins are expressed with the participation of insulin, while others are insulin-independent. chelating metals, which contain chelating metals, absorb glucose from plasma without any involvement of mechanisms triggered by insulin [22]. The central nervous system, adrenal glands, gonads, and retina have a special supply of chelating metals, although at the same time, connective tissue, leukocytes, skin, gastrointestinal organs, and bone marrow are highly insulin-dependent organs, tissues, and cells [29, 31], which may mean that they also depend on Zn as an important component of insulin.

To maintain the priority glucose supply, to preserve the protection of organs and tissues from acute danger, acute reversible diabetes-like metabolic changes occur in some aspects of metabolism, which also affects the redistribution of chelated metals, especially zinc [30, 32]. Under stress, hyperglycemia of insulin-dependent consumers is also ensured by the fact that glucocorticoids (and to a lesser extent catecholamines) stimulate gluconeogenesis in the liver (6-10 times), which affects the metabolism of Zn and Cu. This also depends on the increased supply of glucogenic amino acids from skeletal muscle, which also contain Zn and Cu, but not in chelated form [33-35]. The overall metal-ligand homeostasis is affected by changes in organs containing metals in any form [36-37].

Lipid metabolism is influenced by stressors. The activity of phospholipase and the release of arachidonic acid from cell membrane phospholipids are strongly inhibited by glucocorticoids, with the participation of leptin, and thus prostaglandin synthesis, membrane composition and ionic permeability, which requires a decrease in the content of Zn and Mg as membrane-stabilizing factors [24, 30, 38, 39]. Under the influence of glucocorticoids, antioxidant systems are stimulated and membrane lipid peroxidation is blocked, which also requires redistribution of Zn and Mg in the body or intake of these metals from the outside with drugs or food [32, 40-42]. The effect of stress is multifaceted on the immune system, as well as on the blood system and hematopoiesis.

Platelet formation is enhanced by glucocorticoids. At the same time, there is an increase in the formation of coagulation factors in the liver, in which cationic proteins (defensins) are involved, as a result, stress leads to an increase in the ability to increase the thrombogenic potential of the blood, erythrocytosis and thrombocytosis, which can lead to disseminated coagulation syndrome, which also involves glucocorticoids, and possibly sympathetic nerves, with a sharp change in the content of chelating metals [43-44]. Under stress, lymphopoiesis is suppressed, and myelopoiesis is enhanced. Under stress, leukocytopenia naturally develops. J. W. Thorne proposed it, before the development of direct methods for measuring corticosteroid concentrations, as an indirect correlative indicator of the secretory functions of the adrenal cortex [30, 32, 41, 43].

The functions of the gastrointestinal tract also change under the influence of stress. Short-term anorexia can be caused by catecholamines, but glucocorticoids increase appetite. The hollow organs relax and motility decreases, in particular the stomach, intestines and gallbladder, and sphincters close. Due to vasoconstriction, salivary gland secretion decreases, and gastric and pancreatic juice production, gastric secretion acidity, pepsinogen and trypsinogen expression, and the digestive capacity of duodenal and gastric contents increase dramatically. The result of stress is determined by the behavioral functions of the individual and depends on the hormonal background in the phase of recovery from stress and is largely its result for the individual.

Insulin plays an extremely important role in the body's hormonal response to stress. Under the conditions of stressful situations or unfavorable environmental factors, several mechanisms of hormonal regulation can be used:

1) a general increase in the production of glucocorticoids,

2) a change in the spectrum of glucocorticoids towards a relative increase in more active compounds,

3) a decrease in insulin production and at the same time its content in the blood,

4) a combination of these mechanisms [3, 12].

Already in the phase of anxiety, according to G. Selye, corticosteroid increment increases in stressful situations. The content of glucocorticoids in the blood, increased in the phase of anxiety, begins to decrease in the phase of resistance. It can be argued, using the terminology of G. Selye, that insulin characterizes the levels of regulation and plays the role of a "conditioning factor" in the body [4, 24]. The formation of resistance under stress is of great interest. A person in high latitudes can live long enough in conditions of chronic stress, in which a state of resistance is achieved mainly by reducing the insulin content in the blood. It occurs under the influence of potent factors. Such a reaction generally constitutes a stressful state, a general nonspecific adaptive reaction of the body. In this state, the main thing is that a positive background is created for the implementation of specific homeostatic reactions and the body's adaptive and protective capabilities are mobilized (according to G. Selye) [4]. The need to activate the mechanism of general adaptation arises as the intensity of the performed acts of vital activity increases, as well as depending on the increase in strength or duration of the action. General nonspecific adaptive changes, in turn, are closely related to the energy and plastic support of functions by their essence and physiological role. The central nervous system controls adaptive processes. The structures of the hypothalamus, amygdala, reticular formation, and hippocampus, with the participation of various cortical centers, play a major role in this process. The effector part of adaptive reactions, in particular the mechanism of general adaptation, is directly related to changes in the activity of the endocrine ensemble. Any situation in professional activity associated with emotional stress can activate the adrenal function. There is evidence that coaches of hockey teams significantly increase the excretion of adrenaline and norepinephrine during competitions. A similar situation, although not as emotionally intense, occurs when researchers, university professors and management personnel give presentations and lectures. It has been proven in the examination of different groups of managers that the neuro-emotional component of their mental work is expressed in an increase in the excretion of catecholamines, which increases the activity of the sympatho-adrenal system [29, 31, 39].

Lecturing in higher education teachers was accompanied by an increase in the excretion of hormones of the cerebral and cortical layers of the adrenal glands. In various types of mental work, an increase in adrenaline and norepinephrine in the blood was found. During mental work, the excretion of adrenaline mainly increases, as evidenced by the data on urinary excretion of catecholamines. All this stimulates the functions of the pituitary-adrenocortical system [36, 43]. Professional work can lead to an increase in the activity of a number of endocrine glands due to the presence of muscle work or emotional and mental stress. In turn, these changes depend on external working conditions and the daily rhythm of endocrine functions. The activity of the pituitary-adrenocortical and sympathetic-adrenal systems decreases under the influence of fatigue, both during muscle and mental work.

Monotony of work is also a factor that suppresses adrenocortical activity in workers. Anxiety is the basis of any changes in mental state and behavior caused by stress. Prof. Berezin identified anxiety as an essential element of the adaptation process: 1) a feeling of internal tension - it creates severe discomfort, does not have a pronounced shade of threat, and is only a signal of its approach; 2) hyperesthetic reactions - before neutral stimuli become negative, anxiety increases and irritability increases; 3) anxiety itself - manifested by a feeling of an uncertain threat, the central element of the series under consideration. A characteristic feature: inability to predict the time of the threat, inability to determine its nature. As a result of data processing, an erroneous conclusion is drawn due to a lack of facts; 4) fear - anxiety focused on a specific object. The objects associated with anxiety may not be the cause of it. The subject creates the idea that anxiety can be eliminated by certain actions; 5) an increase in the intensity of anxiety disorders - there is a sense of the inevitability of an impending catastrophe; 6) anxious and fearful arousal - the possibility of purposeful activity disappears and disorganization caused by anxiety reaches a maximum [21, 34].

Aging is the result of all the stresses that the body has been exposed to during its life, a rather interesting hypothesis put forward by Selye. In a sense, aging corresponds to the "exhaustion phase" of the general adaptation syndrome and is an accelerated version of normal aging. Any stress leaves behind irreversible chemical changes, especially those caused by vain efforts; their accumulation causes signs of aging in human tissues and organs. Successful activity, whatever it may be, also leaves behind the effects of aging, especially the destruction of brain and nerve cells. But, as Selye notes, a person can successfully cope with work and live a long and happy life if they choose a job that is suitable for them [3-4, 6, 24]. A decrease in the concentration of zinc in blood plasma and its redistribution between organs and tissues is observed under stress, infections, and trauma. These changes are regulated by leukocyte endogenous mediator, a special thermolabile factor. This factor causes a rapid intake of iron, zinc, and most free amino acids into the liver, a decrease in the content of iron and zinc in the blood plasma, and, due to increased synthesis of ceruloplasmin, an increase in the level of copper in the blood plasma. In addition, zinc levels in the body can reduce tissue breakdown products formed under the influence of various stressors. These products bind zinc, can increase the content of zinc compounds in the blood and increase their excretion in the urine, primarily amino acids. Stress also leads to an increase in the release of corticosteroids into the plasma, which stimulate the intake of zinc into the tissues. Copper plays an important role in the transmission of nerve impulses. The binding of GABA receptors by GABA receptors is significantly increased in the presence of copper deficiency in rat brain synapses, which may be one of the causes of CNS disorders in copper deficiency. It has been established that the copper content in the human body affects the processes of biosynthesis or release of neuropeptides and their level [12, 18, 33, 38]. The concentration of copper in the blood increases under the influence of various pathological factors, acute and chronic inflammatory processes, and chronic infectious diseases [40, 42].

Such a significant number of hypercapnic conditions have both common, and most likely, specific factors of pathogenesis. Stress is one of the common factors [6, 28, 35]. Magnesium deficiency reduces the body's antioxidant capacity, which has been proven to cause changes in the Mg/Ca ratio in adrenal cortex cells, which leads to increased secretion of mineralocorticoids, which can further stimulate magnesium loss. Thus, scientists prove that stress and magnesium deficiency are interrelated, and the restoration of magnesium in cells increases the body's resistance to stress. Thus, magnesium is considered an anti-stress metal [9, 12, 17]. Pathological changes in magnesium content against the background of increased blood copper concentration are formed under stress conditions, when neurohumoral regulatory systems are shifted. [22, 35].

1.2. The use of dietary supplements of plant origin in the modeling of food products for people in conditions of constant stress

Based on the analytical research conducted, experts of the scientific and industrial association "Zhytomyrbioproduct" concluded that the use of natural protectors, namely dietary supplements of plant origin made from domestic raw materials, has a positive effect (table 1). They recommend using products made from raw materials that grow in the human habitat. No dietary supplement has been found that would fully satisfy the physiological daily requirement of people under constant stress by 10...50% of the above substances, but the modeled compositions of meal (or fiber) contain the following list of minerals (Zn, Fe, Cu and Mg/Ca). In order to design food product compositions for people under constant stress, we calculated and presented in Table 1 the indicators of the biological value of dietary supplement compositions, namely the content of micro- and macronutrients.

The calculations show that the content of components that are natural antistressors in dietary supplements meets the daily requirement of a person under constant stress in the range of 10% to 50%:

- zinc contains from 3.3 to 35 mg%: when using 5...53 g of wheat germ meal or 72...252 g of pumpkin fiber or in the composition of dietary supplements in food products;

- iron in various dietary supplements - from 8.7 to 26.9 g%: when using 7.5...37.5 g of amaranth meal or 5.4...27.2 g of oat meal, the defined limits of daily requirement are met;

- magnesium - from 40.0 to 210.0 mg%: when using 12.9...67.8 g of amaranth meal or 11.3...58.9 g of pumpkin fiber, or 13.4...71 g of flaxseed meal, it provides the defined limits of daily requirement. In dietary supplements, the content of components

Table 1 - Chemical composition of micro- and macro-elements of dietary supplements of plant origin of scientific and industrial association "Zhytomyrbioproduct"

Element	Concentration of micro- and macroelements мg/100g in dietary supplements of plant origin					
	Амarant h	Vives	Pumpkin	Wheat germs	Spotted thistle	Flax
1	2	3	4	5	6	7
S (Sulfar)	260278,9	153048,1	95187,7	41605,3 1	90725,78	239456,6
K (Potassium)	304830,4	133198,8	242863,4	360402, 2	326701,1	460149,3
Ca (Calcium)	137000	62000	62000	87000	687000	162000
Mn (Manganese)	1450,13	1616,08	1249,97	6107,25	933,39	1066,15
Fe (Iron)	24000	33000	23000	21000	22000	21000
Cu (Copper)	317	552	863	498	708	1260
Zn (Zinc)	3830	11700	13800	66100	6890	4550
Se (Selenium)	63,42	23,9	39,73	80,92	17,57	170,91
Br (Bor)	467,01	192,53	244,06	300,74	556,34	412,20
Cr (Chromium)	11,44	-	-	169,28	-	-
Ni (Nickel)	-	59,25	-	140,32	-	84,27
Co (Cobalt)	-	29,20	32,48	-	-	-
Cl (Chlorin)	103000	54000	46000	161000	124000	11000
Mg (Magnesium)	311000	281000	357000	205000	327000	296000
P (Phosphorus)	660000	620000	980000	920000	670000	870000

Source: [45]

provides the daily human need under conditions of constant stress in the range of 10% to 30%:

- iron in various dietary supplements - from 8.7 to 26.9 g%: when using 7.5...37.5 g of amaranth meal or 5.4...27.2 g of oat meal, the defined limits of daily requirement are met;

- magnesium - from 40.0 to 210.0 mg%: when using 12.9...67.8 g of amaranth meal or 11.3...58.9 g of pumpkin fiber, or 13.4...71 g of flaxseed meal, it provides the defined limits of daily requirement. In dietary supplements, the content of components provides the daily human need under conditions of constant stress in the range of 10% to 30%:

- Calcium - from 50.0 to 360.0 mg% (when using 7.4...52.5 g of milk thistle or 30.9...222 g of flaxseed meal, it meets the defined limits of daily requirement)

- chromium - from 3.0 to 10.5 mg% (if 27.0...92.5 g of amaranth meal or 30.9...374 g of wheat germ meal is used, it meets the defined limits of daily requirement)

copper - from 1.3 to 25.0 μg%, provided that 0.15...2.9 g of pumpkin fiber or 0.105...2.0 g of flaxseed meal provides the defined limits of daily requirement).

Also, in order to design food product compositions for people under constant stress, it is necessary to study the indicators of the biological value of algal additives, namely the content of dietary fiber, vitamins, micro- and macronutrients, which are given in the monograph "Innovative technologies of food products for functional purposes", which are given in table 2.

Thus, the consumption of the proposed dietary supplements of plant origin in the range of 2.0...71.0 g of flaxseed meal guarantees the provision of 10-30% of the daily requirement for copper, calcium and magnesium; in the range of 0.15...58.9 g of pumpkin fiber guarantees the provision of 10-50% of the daily requirement for copper and magnesium; in the range of 5...53 g of wheat germ meal guarantees the provision of 10-30% of the daily requirement for zinc; in the range of 27.0... 92.5 g of amaranth meal guarantees the provision of 10-50% of the daily requirement for chromium and iron; within 5.4...27.2 g of oat meal guarantees the provision of 10-50% of the daily requirement for iron or more in human food products under conditions of constant stress, which is modeled, guarantees the provision of the daily requirement for especially deficient micronutrients containing components that are natural antistressors.

The presented calculations confirm that when modeling human food products under conditions of constant stress, it is advisable to choose compositions of dietary supplements with wheat germ or pumpkin seed fiber in a composition with spirulina, as well as with pectin-zosterin or cystosira to enrich the food composition of Zn, Fe, Cu and Mg/Ca; compositions of dietary supplements with pumpkin, flax and oat seed meal in a composition with cystosira with pectin-zosterine or zoster.

Table 2 - Chemical composition of algae (per 100 g of product)

Substance	Laminaria	Cystosira	Spirulina	Zostera
1	2	3	4	5
Polysaccharides, g:				
manin	10,6	6,8	–	4,9
Alginic acid	28,5	23,3	–	–
zosterin	–	–	–	21,7
Asshines	27–35	22,9	7	13,2
Vitamin, мg:				
carotenoids	211	217	170	245
folacin	0,06	0,08	0,05	0,07
thiamin	5,7	6,1	5,5	5,9
tocopherol	11,3	10,7	19,0	12,7
niacin	11,5	10,9	11,8	11,3
cyanocobalamin	0,14	0,14	0,16	0,12
Mineral substances, мg:				
calcium	1200	1170	118	4240
phosphorus	98	96	828	106
sodium	2400	1070	34	254
мagnesium	400	505	166	829
potassium	620	720	143552,8	696
iron	40–56	31	–	307
manganese	8,9	8,6	–	25
cobalt	2,5	1,1	0,05	0,37
iodine	108–230	75–114	3,3	102
zinc	39	27	–	7,6
copper	4,1	2,2		1,56

Source: [46]

The specific requirements of dietetics for humans under constant stress require a radical change in the idea of developing food compositions and food production technologies for people under constant stress (table 3). For modeling, we selected food technologies that are problematic from the point of view of dietetics. The analysis of the chemical composition of traditional food products (fig. 2) shows a significant discrepancy between the product formula and the requirements of a rational diet. Traditional sweet dishes (plum sambuco, strawberry mousse, vegetable and berry juices with pulp) contain a large amount of mono- and disaccharides, which is unacceptable from the point of view of rational nutrition, the formula of analog

Table 3 - Chemical composition of traditional and developed dessert products per 100 g of products

Food	Protein content, g%	Fat content, g%	Carbohy-drate content,r%	Dietary fiber content, g% (% of dietary needs)	Energy value, kcal/100g	Product formula
1	2	3	4	5	6	7
Plum Elderberry	4,72	0,4	52,4	1,95(4,8)	238,2	1:0,1:11,1
Elderberry «Gift»	3,25	2,51	11,2	6,48(16,2)	72,6	1:0,8:3,5
Strawberry mousse	2,47	0,07	13,1	0,6(1,7)	65,9	1:0,03:5,3
Mousse «Pumpkin»	2,44	2,06	8,6	15,4(38,5)	64,8	1:0,85:3,5
Apple mousse on cemolina	0,9	0,2	20,3	0,5 (1,2)	81,1	1:0,2:22,5
Mousse «Apple»	3,98	1,96	7,87	5,5(13,8)	64,6	1:0,5:2,0
Vegetable smoothie on a yogurt basic	1,0	0,1	2,9	0,7 (1,8)	17,2	1:0,1:2,9
Smoothie «Yogurt»	3,03	2,4	12,5	8,8 (22,0)	86,7	1:0,8:4,1
Grape-raspberry juice	0,6	0,4	12,3	2,0(5,0)	57,7	1:0,6:22,4
Smoothie «Grape-raspberry»	3,2	2,8	13,3	3,4(8,5)	94,3	1:0,9:4,2
Berry juice with pulp and honey	0,8	0,4	15,1	3,08(7,7)	70,2	1:0,5:18,9
Smoothie «Berry»	4,2	3,4	17,5	3,15(7,8)	121,5	1:0,8:4,2
Orange smoothie	1,11	0,17	9,55	2,1 (5,2)	46,7	1:0,15:8,6
Smoothie «Orange Paradice»	3,98	1,96	7,87	5,5(13,8)	64,65	1:0,5:2,0

Author's development

products shows an excess of carbohydrates compared to protein: for whipped desserts

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- by 5.3...11.1 times, for smoothie analogs - by 2.9...22.4 times. Therefore, as a result of modeling whipped dessert products, namely sambuca "Dar", mousses "Pumpkin" and "Apple", and drinks - smoothies "Yogurt", "Grape-Raspberry", "Berry" and "Orange", food compositions were obtained that, due to their natural sweetness, allow you to avoid using sugar at all and meet the formula of food products for people under constant stress.

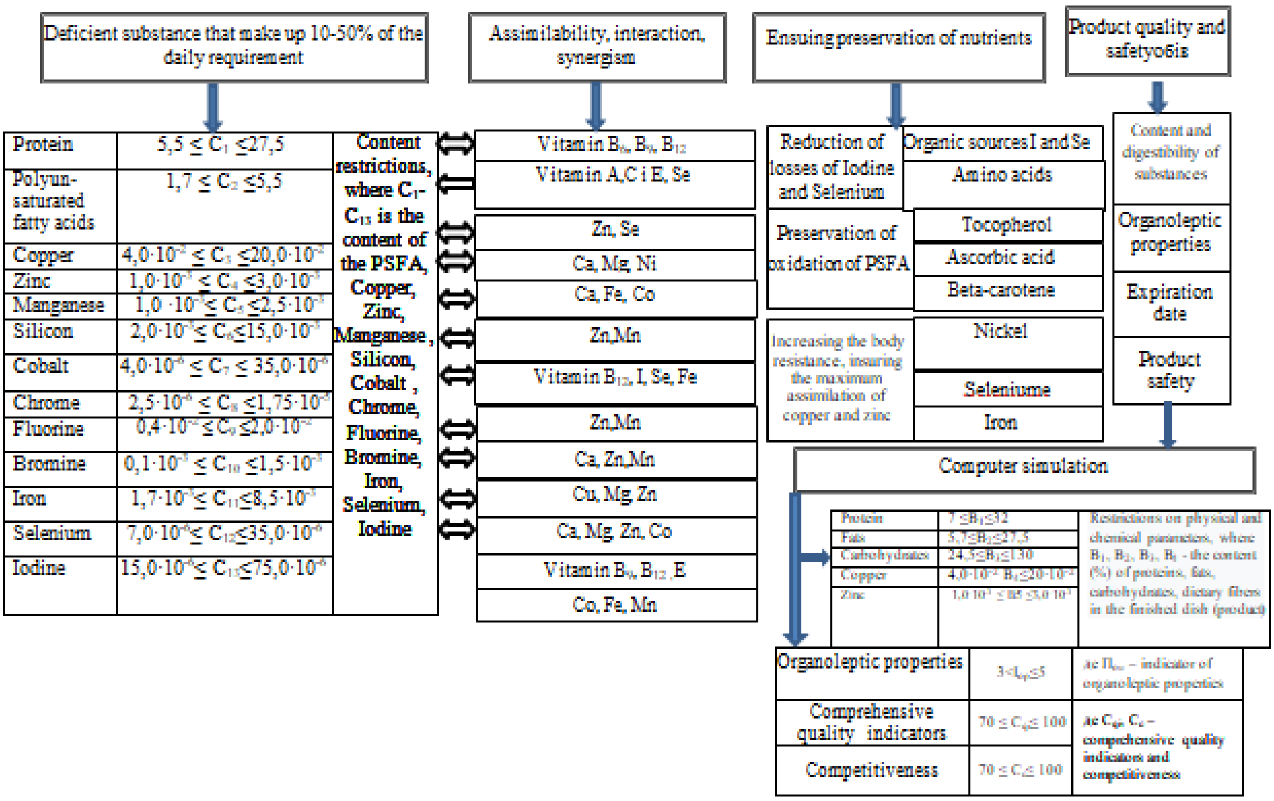

fig. 2 - Modeling the nutritional composition of special culinary products for people in a state of constant stress

Author's development

To prevent the modeling of food compositions containing competing nutrients, a scheme of interaction of nutrients in the modeled food compositions of whipped desserts for people under constant stress was developed (fig. 2). As a result of computer modeling of whipped dessert products for people under constant stress (fig. 3), vegetables (pumpkin, celery), fruits (plum), berries (cranberries, black currants, strawberries), wheat germ meal and pumpkin seed fiber were selected from the list of food raw materials, spirulina and cystose as a source of vegetable proteins, antioxidant vitamins, dietary fiber and minerals (Zn, Fe, Cu and Mg/Ca), egg white and gelatin as a source of animal protein and collagen. By choosing these raw materials, it becomes possible to change the formula of traditional sambuca (1:0.1:11.1 to 1:0.8:3.5), which makes it fundamentally impossible to use traditional dessert products in the diet of people under constant stress. The selected food compositions provide the content of minerals in whipped desserts at the level of 12.6...54.7% of the daily requirement, while in traditional products the mineral composition, except for calcium, iron and copper, did not exceed 10% of the daily requirement.

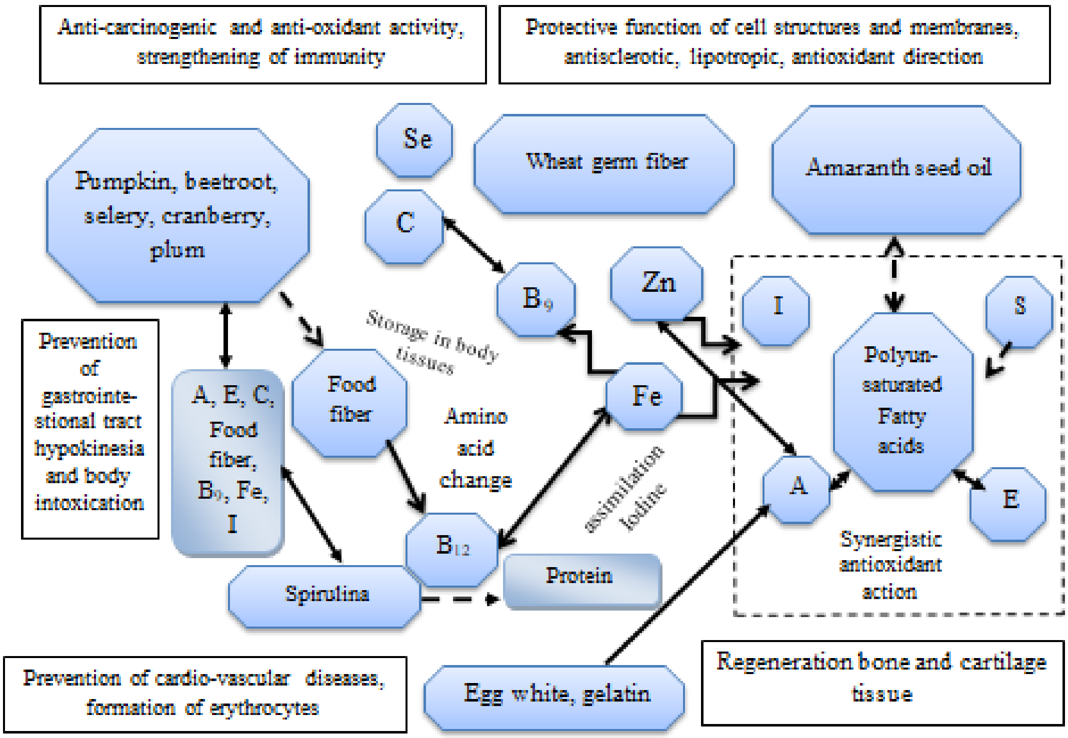

Fig. 3 - Ensuring the interaction of nutrients in whipped desserts for people in conditions of constant stress

Author's development

When modeling the food compositions of the smoothies "Yogurt", "Grape-Raspberry", "Berry-Honey", "Orange Paradise" (fig. 4), yogurt-based vegetable smoothies, grape-raspberry juice, celery and orange juice, and berry juice with pulp and honey were used as the base, respectively, vegetables (green onions, cucumbers, tomatoes), fruits (oranges), berries (grapes, raspberries, strawberries, kiwi) were selected, spirulina as a source of vegetable proteins, antioxidant vitamins, dietary fiber and minerals (iron, iodine, selenium), yogurt with 1 and 1.5% fat content as a source of animal complete protein, pectin-zosterol, wheat germ meal and pumpkin seed fiber due to its dietary fiber content. A scheme of interaction of nutrients in the modeled food compositions of smoothies was developed (fig. 4).

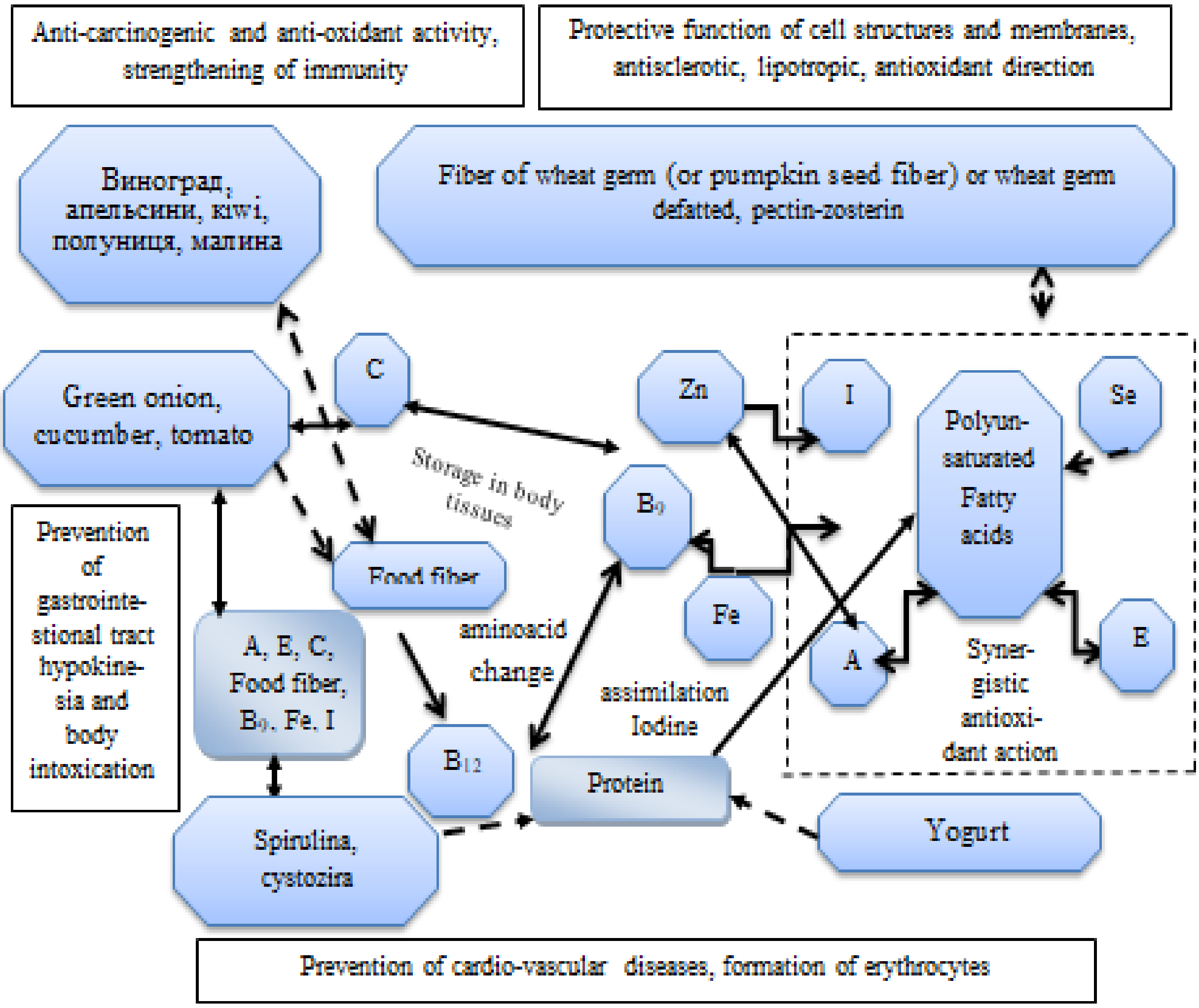

Fig. 4 - Ensuring the interaction of nutrients in smoothies for people in conditions of constant stress

Author's development

The modeled food compositions meet the requirements of rational nutrition for people under constant stress, radically change the product formula compared to the analog product: for Yogurt smoothie (1:0.1:2.9 to 1:0.8:4.1), for Grape-Raspberry smoothie (1:0.6:22.4 to 1:0.9:4.2), for Berry-Honey smoothie (1:0.5:18.9 to 1:0.8:4.2), for Orange Paradise smoothie (1:0.15:8.6 to 1:0.5:2.0). The content of minerals in the portion of the developed smoothies is provided at the level of 12.7...90.0% of the daily requirement, while in traditional products the mineral composition, except for calcium, magnesium and zinc, did not exceed 10% of the daily requirement. The modeled food compositions meet the requirements of rational nutrition for people under constant stress, radically change the product formula compared to the analog product: for Yogurt smoothie (1:0.1:2.9 to 1:0.8:4.1), for Grape-Raspberry smoothie (1:0.6:22.4 to 1:0.9:4.2), for Berry-Honey smoothie (1:0.5:18.9 to 1:0.8:4.2), for Orange Paradise smoothie (1:0.15:8.6 to 1:0.5:2.0). The content of minerals in the portion of the developed smoothies is provided at the level of 12.7...90.0% of the daily requirement, while in traditional products the mineral composition, except for calcium, magnesium and zinc, did not exceed 10% of the daily requirement.

All fats contained in traditional pates are mostly saturated, and the chemical composition of traditional pate products (table 4,5) shows that the fat component exceeds the protein component by 31 times. Hygienists also state that the growth of age-related pathology in Ukraine is directly related to the amount of dietary fiber, antioxidant vitamins, B vitamins, minerals, and cholesterol content in the diet, which is so rich in these products. The formula of traditional pâté products is unbalanced and has a sharp shift towards the content of animal proteins and saturated fats, which does not meet the requirements for specialty products for people under constant stress. Therefore, it is the design of ground meat and fish products that meet these requirements that is relevant.

When modeling the food compositions of chopped meat products (meat pates), in particular, "Amatory", "Morskoy", and "Kharkiv" pates (fig. 5), the following pate recipes were used as basic ones, respectively: meat pate in a shell - "Belovezhsky", No. 159 "Liver pate", and "Metropolitan" of the highest grade.

To create the food compositions of Amatory, Sea, and Kharkiv pates, meat and offal were selected as a source of animal protein and collagen, vegetables (onions and carrots) and cystose and spirulina, pumpkin seed meal or defatted wheat germ as a source of vegetable proteins, antioxidant vitamins, dietary fiber, and minerals (iron, copper, zinc, and others); wheat germ fiber or pumpkin seed fiber and pectin-zosterine due to the content of dietary fiber. Obviously, by choosing these raw materials, it becomes possible to balance the fat and protein component of the product in accordance with the requirements of a healthy diet for people under constant stress.

Table 4 - Chemical composition of traditional and developed meat and fish minced products per 100 g of products

Food	Protein content, g%	Fat content, g%	Carbohy-drate content,г%	Dietary fiber content, g% (% of dietary needs)	Product formula
1	2	3	4	5	6
Meat pate «Belovezhsky»	5,5	0,2	3,6	0,5(1,3)	1:0,03:0,7
Pate «Amatorsky»	12,2	11,4	5,4	1,9(4,8)	1:0,9:0,4
Liver Pate (№159)	1,6	21,8	4,3	1,7(4,0)	1:13,6:2,7
Pate «Sea»	12,8	10,9	14,7	9,7(24,3)	1:0,9:1,1
Pate «Capital» highest grade	1,5	46,6	5,0	3,0(7,5)	1:31:3,3
Pate «Kharkiv»	14,1	11,1	14,1	9,5(23,8)	1:0,8:1
Fish slices № 1.247	17,1	33,6	11,3	1,0(2,4)	1:2:0,7
Fish slices «Pearl»	21,7	19,6	14,7	4,6(11,5)	1:0,9: 0,7
Zander samples	12,1	7,4	12,1	1,4(0,8)	1:0,6:1
Fish samples «Spicy»	14,6	12,9	12,4	8,9(22,3)	1:0,9:0,9

Author's development

Thus, the formula of "Belovezhsky" pate on Ukrainian bread is 1:0.1:3.5, while for the developed "Amatorsky" pate on Ukrainian bread it is 1:0.8:3.6, which fully complies with the principles of special nutrition for people under constant stress. The content of vitamins and minerals in a portion of the developed pate, for example, Amatorsky pate on Ukrainian bread, is provided at the level of 14.1...37.1% of the daily requirement, while in traditional products the mineral composition ranges from 0 to 15.8% of the daily requirement. A scheme of interaction of nutrients in the modeled food compositions of pates was developed (fig. 5).

Table 5 - The content of mineral substance is relative to the daily requirement in meat and fish minced products per 100 g of products

Food	The content of mineral substance is relative to the daily requirement,%						
	zinc	iron	calcium	мagnesium	copper	silicon	selenium
1	2	3	4	5	6	7	2
Meat pate «Belovezhsky»	0,28	2,5	25,5	23,3	5,6	0,07	0,001
Pate «Amatorsky»	0,302	5,1	77,9	36,9	47,9	9,08	25,0
Liver Pate (№159)	0,28	2,5	25,5	23,3	5,6	0,07	0,001
Pate «Sea»	58, 2	5,71	60,5	48,0	54,3	12,8	35,0
Pate «Capital» highest grade	0,28	2,5	22,5	9,5	5,6	0,07	0,001
Pate «Kharkiv»	48, 2	15,1	40,5	36,3	43,3	22,8	27,0
Fish slices № 1.247	2,6	3,9	9,6	7,4	5,6	0,07	0,001
Fish slices «Pearl»	12,5	7,8	23,9	24,5	27,8	32,7	28,6
Zander samples	3,4	1,0	2,67	2,8	5,6	0,07	0,001
Fish samples «Spicy»	18,7	16,7	45,8	23,9	34,6	28,2	33,05

Author's development

The modeling took into account the interaction of nutrients in the modeled food (pates) of the special food for people under constant stress of the composition of fish cuttings and developed a scheme for ensuring the interaction of nutrients (fig. 6). The modeling of the basic food composition of fish cuttings "Pearl" was carried out on the basis of the analog formulation "Ukrainian fish cuttings No. 1.247"; the formula of traditional products is shifted towards fats, their amount exceeds proteins twice, which, from the point of view of special nutrition for people under constant stress, needs to be adjusted. Therefore, when modeling the nutritional composition of fish cakes "Pearl", pike perch fillet and chicken egg were selected as a source of animal protein, zoster, vegetables (onions, carrots, parsley) and pumpkin seed meal as a source of vegetable proteins, antioxidant vitamins, dietary fiber and minerals.

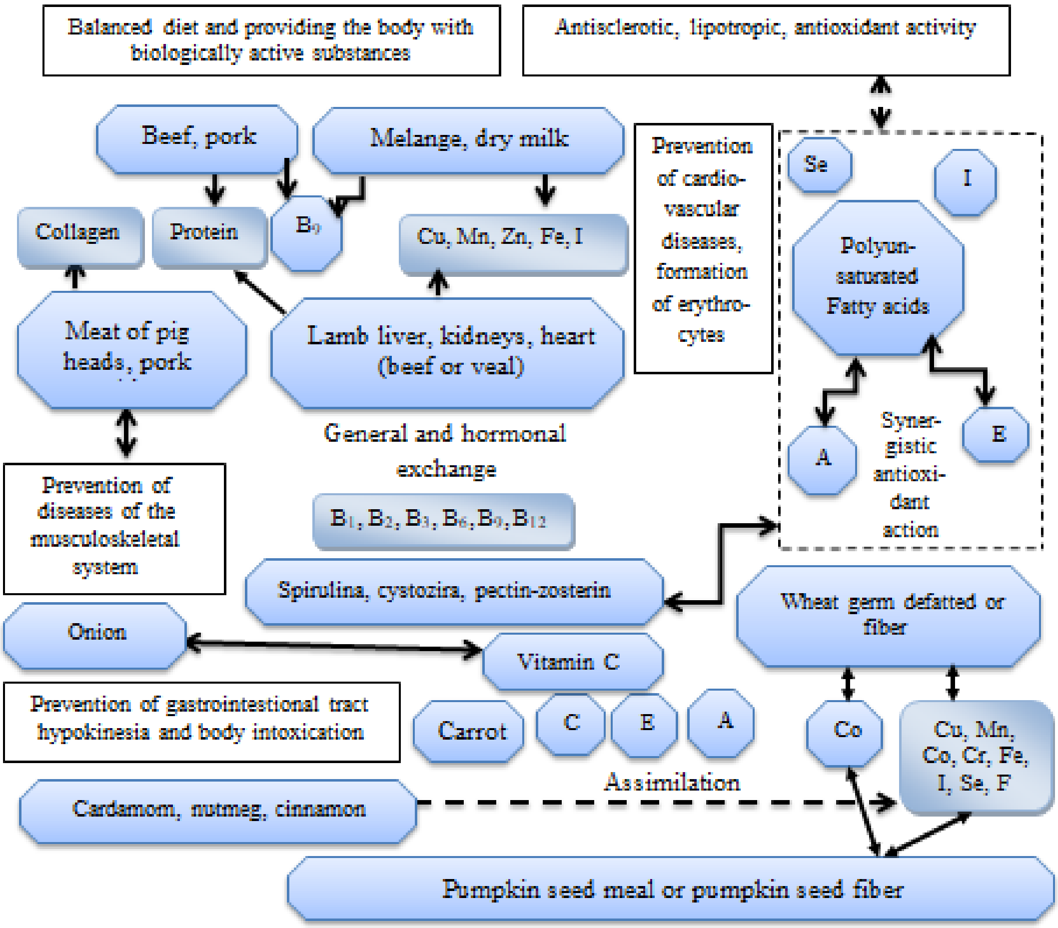

Fig. 5 - Ensuring the interaction of nutrients in minced meat products for people in conditions of constant stress

Author's development

The formula of the developed fish cutlets is 1:0.9:0.7, i.e. the carbohydrate component can be balanced by adding a carbohydrate garnish, such as boiled rice, in which case the formula of the dish will be 1:0.9:3.5.

The amount of flour recommended for use in special nutrition diets for people under constant stress is limited to 40-60 g/day, although flour dishes and products (dumplings, pancakes) are traditionally Ukrainian dishes. The chemical composition of traditional flour products, both culinary and confectionery (table 6,7), demonstrates an imbalance in the direction of carbohydrates, both starch and mono- and disaccharides.

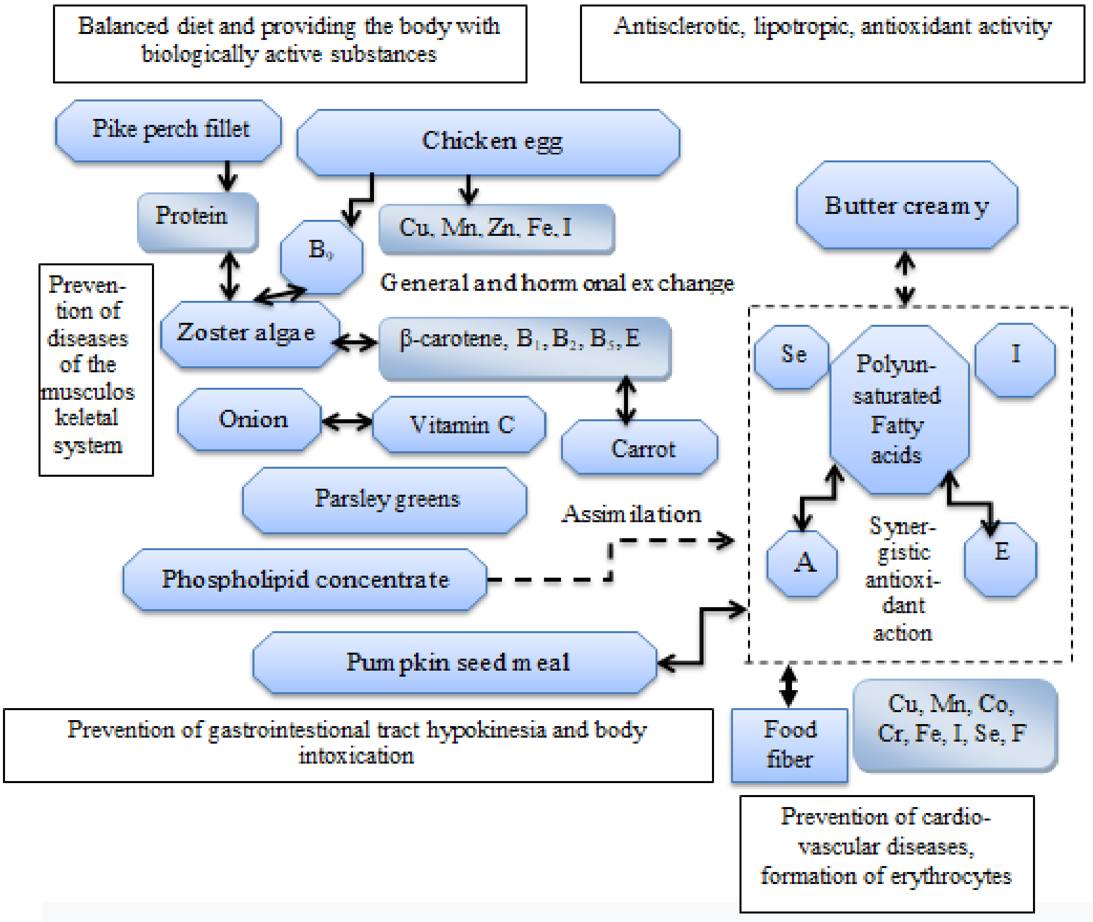

Fig. 6 - Ensuring the interaction of nutrients in minced fish products for people in conditions of constant stress

Author's development

The energy value of traditional flour products is 2 times higher than the permissible limit of 200 kcal recommended for people under constant stress. Moreover, the content of the fat component is somewhat underestimated, for example, for dumplings it is 20% of the protein component, while carbohydrates exceed proteins up to 6 times, which means that the consumption of traditional flour products is not recommended in terms of rational nutrition for people under constant stress. Thus, it is necessary to design flour products that are nutritionally adequate to the needs of people under constant stress. Modeling of the nutritional composition of flour products allowed us to create nutritional compositions of Cheese dumplings, Cheese pancakes, and Charivnytsia muffins. The recipes of "Cheese dumplings", "Cheese pancakes" and "Cheese muffins" were used as the basic ones.

Table 6 - Chemical composition of traditional and developed flour and cheese products per 100 g of products

Food	Protein content, g%	Fat content, g%	Carbohy-drate content,г%	Dietary fiber content, g% (% of dietary needs)	Energy value, kcal/100g	Product formula
1	2	3	4	5	6	7
Varenyky with cheese	14,1	3,3	30,5	2,2(8,7)	257,1	1:0,2:2,2
Varenyky «Cheese»	8,9	7,4	24,0	2,3(9,0)	204,2	1:0,8:2,7
Fritters	4,8	7,0	25,0	1,5 (3,8)	187,9	1:1,5:5,2
Fritters «Cheese»	7,3	6,4	23,0	1,9 (4,8)	184,7	1:0,9:3,2
Cheese muffins	8,4	16,7	51,0	1,3(5,2)	399,2	1:2:6,1
Muffins «Charivnytsa»	11,6	10,3	30,2	2,2(5,5)	267,8	1:0,9:2,6
Cheese pudding	13,9	9,6	20,1	1,4	224,0	1:0,7:1,45
Pudding «Cheese delight»	17,3	26,4	27,8	7,1 (17,8)	418,0	1:1,5:1,6
Cheese casserole	17,6	4,2	14,2	0,4	168,0	1:0,2:0,8
Casserole « Cheese delight»	11,6	16,2	23,2	0,4	168,0	1:1,4:2,0

Author's development

The food compositions include fermented dairy products (sour cream 10% fat, sour cottage cheese 4% fat, kefir 1% fat, mélange and spirulina as a source of animal and vegetable proteins, B vitamins and minerals (calcium, phosphorus, magnesium, potassium and iron); kiwi and dried apricots as a source of antioxidant vitamins, dietary fiber and minerals; wheat germ and pumpkin meal for their dietary fiber and mineral content. Such a set of raw materials made it possible to balance the formula of special products for people under constant stress: dumplings 1:0.8:2.7, pancakes 1:0.9:3.2 and muffins 1:0.8:2.7 and 1:0.9:2.6, which is significantly different from the formula of analog products: "Dumplings with cottage cheese" (1:0.2:2.2); pancakes (1:1.5:5.2); muffins (1:2:6.1).

Table 7 - The content of mineral substance is relative to the daily requirement traditional and developed flour and cheese products,%

Food	The content of mineral substance is relative to the daily requirement,%					
	zinc	iron	calcium	мagnesium	copper	silicon
Varenyky with cheese	4,1	6,0	0,3	6,5	5,6	1,5
Varenyky «Cheese»	12,2	55,0	58,9	6,6	37,1	14,8
Fritters	3,9	4,0	0,9	5,6	2,0	2,9
Fritters «Cheese»	11,1	29,3	12,9	6,0	12,1	8,3
Cheese muffins	7,7	7,3	0,2	3,0	6,2	2,9
Muffins «Charivnytsa»	8,5	26,7	10,0	4,3	15,3	8,6
Cheese pudding	3,7	6,9	13,0	23,6	7,5	3,5
Pudding «Cheese delight»	21,8	32,3	25,9	36,0	42,1	18,3
Cheese casserole	5,9	16,5	11,3	23,0	12,0	7,9
Casserole «Cheese delight»	25,3	32,5	17,8	26,3	32,4	28,6

Author's development

A scheme of interaction of nutrients contained in the modeled food compositions of flour products was developed (fig. 7).

To create the food compositions of cottage cheese pudding and casserole "Cheese Delight", sour cottage cheese and chicken eggs were selected as a source of animal protein, vegetables (carrots) and cystose and spirulina, pumpkin seed meal or defatted wheat germ as a source of vegetable proteins, antioxidant vitamins, dietary fiber and minerals (iron, copper, zinc, etc.); wheat germ fiber or pumpkin seed fiber and pectin-zosterine due to their dietary fiber content. By choosing these raw materials, it becomes possible to balance the side-fat component of the product in accordance with the requirements of a rational diet for people under constant stress. For example, the formula of curd pudding is 1:0.7:1.45, while for the developed pudding "Cheese Delight" it is 1:1.5:1.6, which fully complies with the principles of special nutrition for people under constant stress. The content of vitamins and minerals is provided at the level of 18.3...42.1% of the daily requirement, while in traditional products the mineral composition ranges from 3.5 to 23.6% of the daily requirement.

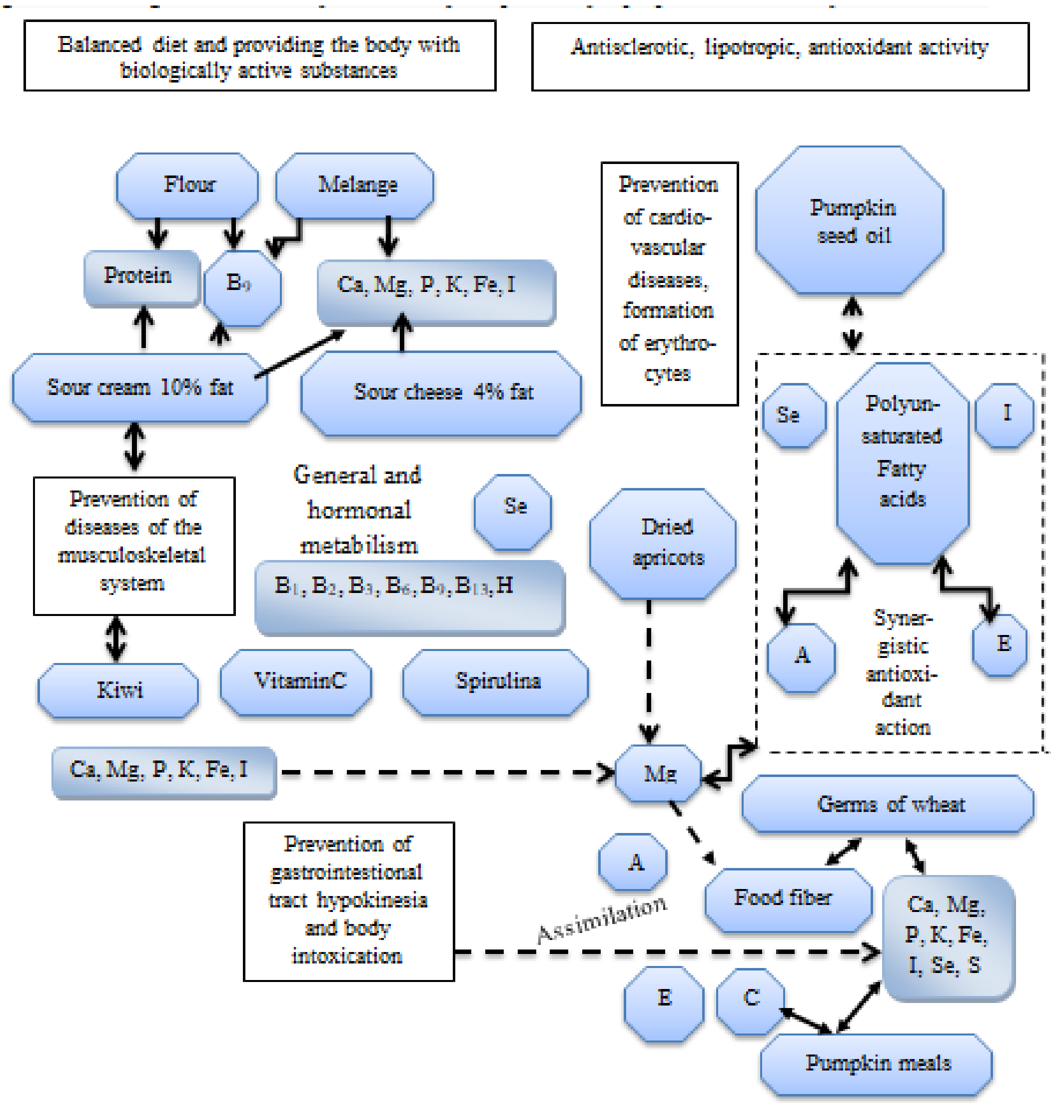

Fig. 7 - Ensuring the interaction of nutrients in flour products for people in conditions of constant stress

Author's development

The formula for the portion of the developed casserole "Cheese delight" is 1:1.4:2.0, for the traditional casserole "Cheese" – 1:0.2:0.8, the content of vitamins and minerals is provided at the level of 17.8...32.4% of the daily requirement, while in traditional products the mineral composition ranges from 3.6 to 23.0% of the daily requirement.

1.3. Modeling the daily food ration for people under conditions of constant stress

Able-bodied Ukrainians consume approximately, according to the Government's Resolution of October 11, 2016, No. 780 No. 780, 44 kg of meat, poultry and lard, 13 kg of fresh, frozen and salted fish, more than 7 kg of various cereals, about 4 kg of pasta, almost 2 kg of legumes, 95 kg of potatoes and the same amount of other vegetables, as well as about 60 kg of various fruits and berries, which together amounts to a consumption of more than 650 kg of various foods per year and almost 55 kg per month.

The generalized data on the nutritional composition of the food rations of Ukrainian military personnel show that the proportions of the main nutrients are practically not taken into account when preparing the rations, the formula of the rations practically does not coincide with the recommended one, i.e., the fluctuations in nutrients compared to the recommended norms of rational nutrition were up to 50%. Thus, the results of the study of the diet of Ukrainian military personnel suggest that their nutrition requires significant changes in both the set of products and the principles of daily menu preparation, including the development of a model for the distribution of energy value between food groups in the daily diet of special purpose, taking into account the development of a general formula for the diet of people under constant stress.

In accordance with the conclusions, we have developed and proposed a model for the distribution of energy value between food groups in the daily diet for special purposes (fig. 8). In accordance with the proposed model, an exemplary diet for people under constant stress was developed for specialized institutions engaged in the rehabilitation of military personnel, which includes special-purpose food products for people under constant stress using dietary supplements of plant origin, which made it possible to balance the general formula of the food ration and take into account the requirements of rational nutrition for the content of dietary fiber, cholesterol, minerals, antioxidant vitamins, etc.

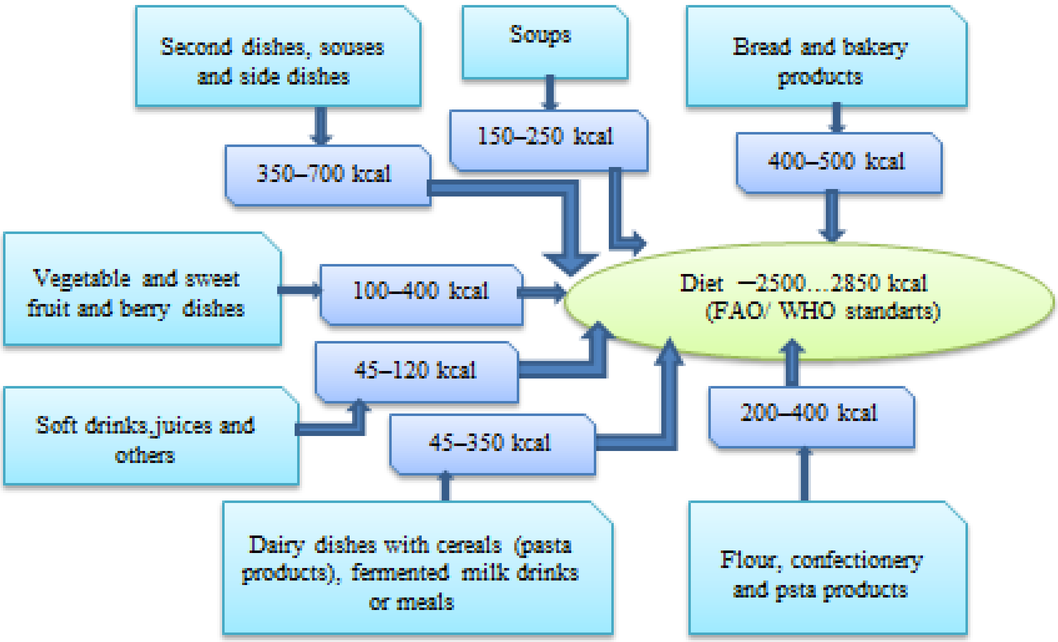

Fig. 8 - Distribution of energy value between groups of food products of special purpose for people in conditions of constant stress

Author's development

The proposed food ration for special purposes includes the developed products and was tested in the Territorial Rehabilitation and Social Service Center of the Ulyanovsk District of Kirovograd Region.

The characteristics of the proposed food ration for special purposes are given in table 8. The energy value of the developed and proposed two-week diet, which is recommended for people under constant stress, varies from 2537.3 to 2829.9 kcal/day, the average energy value of the studied diet is 2699.6 kcal, which for men exceeds the requirements of FAO/WHO by 1.25 to 1.38 times and practically meets the requirements of Ukrainian scientists (2790.8 kcal/day); it significantly exceeds the

Table 8 - Characteristics of the special purpose food ration

Energy value, daily (kcal)	Nutrient content, g							Diet formula proteins:fats : carbohydrates
	proteins		fats		carbohydrates		Chole-sterol, мg	
	General content	including irrepla-ceable AA	General content	including polyunsa-turated fatty acids	General content	Including food fiber		
2924,9	60,2	42,5	138,5	28,8	349,2	45,9	127,0	1:2,3:5,8
2808,0	59,4	54,7	130,7	40,1	338,6	41,8	149,4	1:2,2:5,7
2657,2	54,7	51,0	125,8	33,5	317,3	32,0	177,7	1:2,3:5,8
2569,3	53,5	44,1	117,7	31,4	314,8	27,6	169,3	1:2,2:5,9
2633,6	54,2	46,2	124,7	39,0	314,4	34,8	117,7	1:2,3:5,8
2827,1	59,8	47,6	131,6	39,8	340,9	35,4	166,6	1:2,2:5,7
2594,0	53,4	49,6	122,8	47,2	309,7	42,4	267,3	1:2,3:5,8
2537,3	51,8	45,8	119,1	35,7	305,6	41,0	165,2	1:2,3:5,9
2584,1	54,2	36,1	119,2	20,6	314,4	44,4	208,8	1:2,3:5,8
2817,2	59,6	57,2	131,1	41,4	339,7	33,6	112,8	1:2,2:5,7
2611,3	53,3	38,8	122,6	38,2	314,5	28,0	279,0	1:2,3:5,9
2718,0	57,5	51,9	126,5	35,5	327,8	34,5	231,7	1:2,2:5,7
2813,1	57,9	37,6	133,2	31,9	335,8	33,0	126,0	1:2,3:5,8
2827,7	58,2	35,9	133,9	28,4	337,6	35,4	185,2	1:2,3:5,8
2708,8	**56,3**	**46,4**	**127,0**	**35,1**	**325,7**	**36,4**	**190,5**	**1:2,3:5,8**

Author's development

requirements for women: FAO/WHO - by 1.51...1.67 times and practically meets the

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requirements of Ukrainian scientists. The limit of the energy value of the diet according to FAO/WHO recommendations is: for men - 2050 kcal/day and for women - 1700 kcal/day.

The characteristics of the developed food ration meet the requirements of rational nutrition; on a daily basis and on average for a two-week diet, they are as follows

- protein component in the energy value of the diet - 8.4...8.7%;
- content of essential amino acids to total protein - from 61.7 to 96.0%;
- the amount of lysine methionine + cysteine phenylalanine + tyrosine in the daily diet is not less than 5.5:3.5:6.0 g
- fat component in the total caloric content is not more than 41.2...42.6%, with vegetable fats - from one fifth to one third, polyunsaturated fatty acids - 20.7...38.4% of the saturated fatty acid content;
- carbohydrate component is 48.9...50.2% of the total caloric content;
- dietary fiber should be in the range of 27.6...44.4 g/day.

The protein content in the proposed diet, namely 51.8...60.2 g/day, exceeds the established norm according to the requirements of Ukrainian scientists (52.0...58.0 g/day for women) and is consistent with the requirements for men (54.0...65.0 g/day), but is less than the requirements of FAO/WHO (63.8...76.9 g/day).

The average daily amount of protein in the proposed diet is 56.3 g/day, which does not meet the FAO/WHO requirements and is 3.7% higher than the level of requirements of Ukrainian scientists for women and is the same as for men. It is known that complete proteins, in addition to plastic and energy functions, play an important protective role, increasing the body's resistance to various infections, toxic agents, as well as neuropsychological stress and stressful situations. With sufficient protein content in the diet, the biological qualities of other nutrients (fats, vitamins, minerals) are most fully manifested.

The fat content in the diet, namely 41.2...42.6 g/day, is within the normal range according to the requirements of Ukrainian scientists and 37.4...45.6% less than the requirements of FAO/WHO (56.7...78.3 g/day).

The average daily amount of fat is 127 g/day, which is 55.4% higher than the requirements of FAO/WHO experts. The share of fat in the total caloric content is reduced to 41.2...42.6%, and the content of vegetable fats is from 1/5 to 1/3 of the total fat. Increasing the amount of fat in the diet of people under constant stress due to the consumption of polyunsaturated fats will help prevent cardiovascular disease and enhance the synergistic antioxidant effect of the diet.

The carbohydrate content in the proposed diet is in the range of 314.4...349.2 g/day, which exceeds the FAO/WHO requirements by 20.0...25.6.0% (233.8...281.9 g/day) and is 23.7% less than the lower limit of the requirements of Ukrainian scientists for women and 2.6% less than the upper limit for men (240.0...270.0 g/day for women and 270.0...300.0 g/day for men). The average daily amount of carbohydrates in the proposed diet is 325.7 g/day, which is 28.3.0% more than the requirements of FAO/WHO experts, 7.9% more than the requirements of Ukrainian scientists for men, and slightly higher for women - by 13.4%.

When developing food rations for people under constant stress, who have diseases of the gastrointestinal tract, cardiovascular system and diabetes, one should strive to reduce the total carbohydrate content in the daily diet, as this helps to reduce the excitability of the autonomic nervous system and increase the content of non-digestible polysaccharides.

An analysis of the mineral and vitamin composition of smoothies introduced into the diet showed that their consumption fully covers the daily requirement for Zn, Fe, Cu and Mg/Ca, as well as vitamins A, C and E. Antioxidant vitamins are essential for the prevention of age-related diseases. Foods rich in potassium, zinc, copper, iodine and selenium, i.e. nutritional stress protectors, extend life expectancy and slow down the spread of stress in society. Providing the developed food ration with the daily requirement for chelated metals leads to the prevention of cancer, as well as the antisclerotic, lipotropic, and antioxidant effects of the food ration.

Conclusions.

Thus, the developed diet can be used in organized groups, in particular in rehabilitation centers, boarding houses and health centers, and recommended for the prevention of the spread of stress in society.

A comparative analysis of the studied and developed food rations based on quality models was carried out. The complex quality indicator (CQI) of the developed and studied special-purpose diets covers the following indicators of two-week and separate daily diets: energy value, amount of proteins, fats and carbohydrates, ratio of nutrients, cholesterol content.

KAPITEL 2 / *CHAPTER 2* [2]
PROACTIVE RESOURCE MANAGEMENT IN A KUBERNETES CLUSTER USING AI-BASED RESOURCE USAGE PREDICTION IN THE CLOUD ENVIRONMENT

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Вступ

Хмарні обчислення є ключовим компонентом сучасних технологічних рішень, оскільки вони забезпечують високу гнучкість, масштабованість і ефективність використання обчислювальних ресурсів. У цьому контексті платформа Kubernetes відіграє провідну роль, дозволяючи автоматизувати розгортання, управління та масштабування додатків. Однак, існуючі механізми управління ресурсами, такі як Horizontal Pod Autoscaler (HPA) та Vertical Pod Autoscaler (VPA), спираються на реактивний підхід, що має значні обмеження. Реактивна природа цих механізмів означає, що рішення приймаються лише після фіксації змін у навантаженні. Це призводить до низки проблем, зокрема затримок у масштабуванні, перевитрат ресурсів або їх недостатнього виділення, що, у свою чергу, може спричинити деградацію продуктивності додатків.

В умовах динамічних хмарних середовищ, де навантаження може змінюватися швидко й непередбачувано, виникає необхідність реалізації проактивного управління ресурсами. Такий підхід дозволяє передбачати зміни у використанні ресурсів і завчасно адаптувати систему до нових умов. Використання штучного інтелекту (ШІ) та методів машинного навчання відкриває нові можливості для прогнозування використання ресурсів у кластері Kubernetes. Зокрема, алгоритми прогнозування, такі як аналіз часових рядів (time-series analysis), надають змогу виявляти тренди у використанні ресурсів, що дозволяє оптимізувати витрати на інфраструктуру та підвищувати стабільність роботи додатків. Інтеграція таких алгоритмів у середовище Kubernetes забезпечує не лише економічну ефективність, а й значно покращує загальну продуктивність системи.

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Метою цієї роботи є дослідження підходів до проактивного управління ресурсами у кластері Kubernetes, заснованих на прогнозуванні використання ресурсів із застосуванням сучасних методів штучного інтелекту, зокрема у динамічних хмарних середовищах.

Для досягнення поставленої мети визначено такі завдання:

- Провести аналіз існуючих методів управління ресурсами у Kubernetes, включаючи HPA та VPA, з їх перевагами та обмеженнями.
- Розкрити концепцію проактивного управління ресурсами, визначивши її доцільність та потенційні переваги в умовах динамічних хмарних середовищ.
- Дослідити алгоритми прогнозування, такі як Prophet та LSTM, оцінюючи їхню відповідність задачам масштабування ресурсів.
- Оцінити вплив проактивного підходу на ефективність роботи кластеру Kubernetes, стабільність та економічність використання ресурсів.

Дослідження проактивного управління ресурсами спрямоване на вирішення ключових проблем реактивних механізмів, таких як затримка в адаптації до змін і нераціональне використання ресурсів. Використання ШІ у процесах управління Kubernetes створює можливості для значного підвищення точності прогнозування та ефективності масштабування, що відповідає сучасним вимогам до продуктивності хмарних систем.

2.1. Аналіз існуючих рішень та розкриття концепції проактивного управління ресурсами

У сучасних динамічних хмарних середовищах управління ресурсами є важливим аспектом для забезпечення продуктивності, стабільності та економічної ефективності. Kubernetes пропонує механізми автоматичного масштабування, такі як Horizontal Pod Autoscaler (HPA) та Vertical Pod Autoscaler (VPA), які значно спрощують управління ресурсами в кластері. Однак, вони мають свої обмеження, що знижує їх ефективність у складних сценаріях з мінливим навантаженням [1, 10, 11, 12, 13, 14, 15].

2.1.1. Аналіз існуючих методів управління ресурсами у Kubernetes

Horizontal Pod Autoscaler (HPA) є стандартним інструментом Kubernetes для автоматичного масштабування кількості подів у межах одного додатка залежно від поточного використання ресурсів (CPU, пам’ять) [2]. HPA працює шляхом аналізу метрик, отриманих від Kubernetes Metrics Server, і прийняття рішення про додавання або зменшення кількості подів, якщо поточні значення метрик перевищують або знижуються відносно заданого порогу.

Таб. 1 - Переваги та недоліки HPA.

Переваги	Недоліки
Простота налаштування та використання	HPA відповідає на зміни лише після їх виникнення, що може призводити до затримок у масштабуванні.
Реактивна адаптація до короткострокових змін у навантаженні	Залежність від базових метрик, наприклад, CPU і пам'ять, які не завжди точно відображають поточний стан навантаження
Висока інтеграція з екосистемою Kubernetes	Немає можливості врахувати складні тренди або передбачити довготривалі зміни

Авторська розробка

Тепер розглянемо Vertical Pod Autoscaler (VPA), це інструмент, який автоматично налаштовує запити та ліміти ресурсів (CPU, пам’ять) для кожного поду залежно від його фактичного використання [3]. Він аналізує історичні дані, щоб запропонувати оптимальні параметри або автоматично оновлює їх.

Таб. 2 - Переваги та недоліки VPA.

Переваги	Недоліки
Знижує ризик недостатнього або надмірного виділення ресурсів.	Зміна ресурсних налаштувань вимагає перезапуску подів (сервісу), що може вплинути на безперервність роботи додатка.
Ефективно працює для додатків із стабільним і передбачуваним навантаженням.	VPA не завжди ефективний у ситуаціях із раптовими сплесками трафіку.
	Працює тільки на рівні налаштувань одного поду і не вирішує задачі масштабування кількості подів.

Авторська розробка

2.1.2. Обмеження існуючих рішень

Попри свої переваги, обидва методи базуються на реактивному підході, що значно обмежує їх ефективність у динамічних середовищах із непередбачуваним навантаженням. Основні обмеження полягають у наступному:

- Реактивний характер, тоюто рішення про масштабування приймаються лише після виникнення змін у навантаженні, що може призводити до затримок у реакції системи.
- Неврахування довготривалих трендів - метрики, які використовуються в HPA та VPA, не дозволяють врахувати сезонність або передбачити майбутнє зростання навантаження.
- Обмежений набір метрик - існуючі механізми враховують лише базові показники, такі як CPU і пам’ять, ігноруючи складні залежності між іншими метриками, наприклад, мережею або ввід/вивід.
- Неадаптивність до пікових навантажень - раптові зміни в навантаженні

(наприклад, рекламні кампанії або розпродажі) можуть викликати затримки у масштабуванні, що може вплинути на якість роботи додатків.

Ці обмеження створюють ризик недостатньо швидкої адаптації Kubernetes кластеру до змін у навантаженні, що критично для додатків у складних сценаріях та у динамічних хмарних середовищах.

2.1.3. Концепція проактивного управління ресурсами

Проактивне управління ресурсами — це підхід, який базується на прогнозуванні майбутнього використання ресурсів у кластері. Завдяки цьому рішення щодо масштабування або налаштування ресурсів приймаються не після, а до виникнення змін у навантаженні. Це можливо завдяки використанню алгоритмів машинного навчання та аналізу часових рядів та метрик.

Ключові принципи:

- Для прогнозування використовуються методи машинного навчання та аналізу часових рядів для визначення майбутніх змін у використанні ресурсів.
- Для завчасної адаптації виконуються дії для масштабування ресурсів до того, як система зазнає змін.
- Врахування складних залежностей є здатністю аналізувати взаємозв'язки між різними метриками та враховувати сезонні коливання чи аномалії.

Хмарні середовища, особливо з великим числом користувачів або непередбачуваними навантаженнями, потребують більш адаптивних рішень для управління ресурсами [10, 11, 12, 13, 14, 15]. Наприклад як у стримінгових сервісах вечірній трафік може зростати в кілька разів, і прогнозування дозволяє заздалегідь масштабувати інфраструктуру. А також у фінансових додатках, де піки навантаження можуть бути викликані раптовими подіями, завчасне масштабування допоможе уникнути простоїв.

Основними аспектами обґрунтування доцільності використання проактивного управління є:

- Економічна ефективність яка дозволяє уникнути перевитрат на ресурси, виділяючи їх лише тоді, коли це необхідно.

- Підвищення стабільності - коли система встигає адаптуватися до змін у навантаженні, знижуючи ризик простоїв або збоїв.
- Інтеграція з штучним інтелектом дозволяє обробляти великі обсяги даних і враховувати складні залежності, що робить проактивний підхід більш точним і ефективним.

Таким чином, існуючі методи (HPA, VPA) забезпечують базову функціональність автоматичного масштабування, проте їхній реактивний підхід має суттєві обмеження, що обмежують їхню ефективність у складних сценаріях. Проактивне управління ресурсами, засноване на прогнозуванні, є перспективним рішенням для динамічних хмарних середовищ, яке дозволяє підвищити стабільність, ефективність та економічність роботи кластерів Kubernetes. Інтеграція таких підходів із методами штучного інтелекту відкриває нові можливості для забезпечення продуктивності сучасних систем.

2.2. Експериментальна оцінка моделей для прогнозування навантаження в Kubernetes кластерах

Для розробки та тестування прогнозів було використано підходи, запропоновані у підручнику Hyndman та Athanasopoulos [6], що є основним ресурсом для роботи з часовими рядами. Крім того, для глибшого розуміння архітектури та можливостей Kubernetes було звернено до книги "Kubernetes: Up and Running" [7].

Метою даної роботи є дослідження доцільності та можливості застосування алгоритмів масштабного прогнозування для передбачення навантаження в Kubernetes кластері. Через експеримент перевірити здатність алгоритмів Prophet і LSTM прогнозувати типові патерни навантаження компонентів кластеру.

У рамках дослідження для прогнозування навантажень на кластер Kubernetes було обрано дві моделі, які використовують різні підходи до роботи з часовими рядами:

- Prophet - модель, для прогнозування сезонних патернів, що спеціалізується на аналізі часових рядів з трендами та сезонністю. Цей алгоритм було запропоновано Meta (раніше Facebook) і широко висвітлено у дослідженні [4]. Її особливість - це автоматичне розкладання даних на тренд, сезонність і залишки. Завдяки цьому Prophet добре працює навіть із даними, що мають аномалії чи пропуски. Ця модель дозволяє швидко налаштувати параметри без глибоких знань у сфері машинного навчання.
- LSTM (Long Short-Term Memory) - модель штучної нейронної мережі, яка відноситься до рекурентних архітектур, про що докладно розповідається в роботі Hochreiter та Schmidhuber [5]. LSTM ефективно працює з часовими рядами завдяки своїй здатності “пам’ятати” важливі залежності між значеннями на різних етапах часу.

Для тестування моделей було створені два різних набори даних з різними патернами, які імітують типові сценарії роботи кластеру Kubernetes:

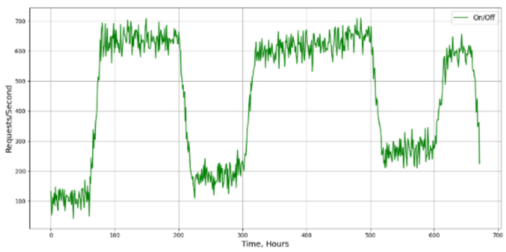

Рис. 1. Тестові дані на основі паттерну піків та нульової активності.

Авторська розробка

Цей тип навантаження характеризується різкими змінами між високими піками (On) і періодами майже нульової активності (Off). Така поведінка часто виникає в кластерах, де сервіси запускаються і зупиняються залежно від потреби, наприклад, під час обробки даних або виконання планових завдань.

У цьому випадку навантаження має чітко виражену сезонність: добову та тижневу. Паттерн змодельовано у вигляді синусоїдальних коливань із додаванням випадкових шумів, що відображає регулярну активність сервісів із періодичними піками та спаданнями.

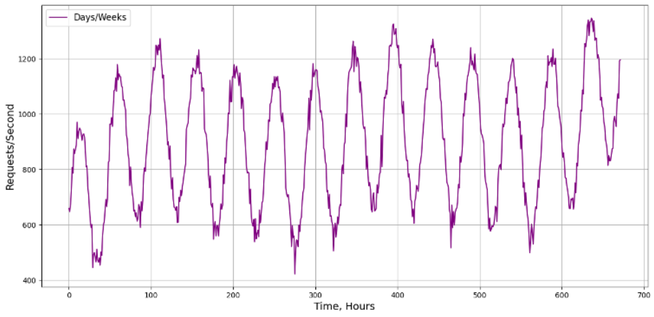

Рис. 2. Тестові дані на основі тижневого паттерну.

Авторська розробка

Мета вибору цих патернів полягала в оцінці продуктивності моделей у різних сценаріях навантаження: від різких змін до довготривалої сезонності. Всі моделі тренувалися на історичних даних довжиною 4 тижні без попередньої обробки, щоб забезпечити універсальність підходу.

Для порівняння точності моделей використовувалися Root Mean Squared Error (RMSE) та Mean Absolute Percentage Error (MAPE) метрики.

Root Mean Squared Error (RMSE) - це міра точності прогнозування, яка обчислює квадратний корінь середнього значення квадратів різниці між фактичними та прогнозованими значеннями. RMSE використовується для оцінки помилок моделі прогнозування, особливо для задач регресії та аналізу часових рядів та обчислюється за наступною формулою:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} (\hat{x}_t - x_t)^2}{n}}, \quad (8)$$

де *n* - кількість спостережень у наборі даних., *y(i)* - істинне значення, *ŷ(i)* - передбачене значення.

Mean Absolute Percentage Error (MAPE) - дана метрика дозволяє виміряти точність прогнозування, яке обчислюється як середнє абсолютне відсоткове відхилення між фактичними значеннями та прогнозами. Розраховується за наступною формулою:

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{\hat{x}_t - x_t}{x_t}\right|, \quad (9)$$

де *n* - кількість спостережень у наборі даних., *y(i)* - істинне значення, *ŷ(i)* - передбачене значення.

Після тренування моделей набором даних на основі паттерну піків та нульової активності, отримали наступні результати:

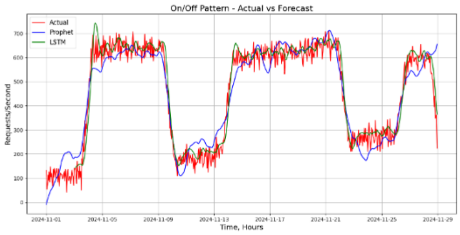

Рис.3. Прогнозування моделей на основі паттерну піків та нульової активності.

Авторська розробка

Патерн On/Off демонструє здатність моделей адаптуватися до різких змін у навантаженні. Метрики продуктивності для обох моделей наведені нижче:

Таб. 3. Результат продуктивності моделей Prophet та LSTM для патерну On/Off

Модель	**RMSE**	**MAPE (%)**
Prophet	243.65	13.89
LSTM	45.96	10.58

Авторська розробка

Як показано на Рис. 3, LSTM значно перевершує Prophet у цьому сценарії. Нижчий RMSE (45.96 проти 243.65) вказує на більшу точність у прогнозуванні різких змін. Крім того, MAPE для LSTM становить 10.58%, що є нижчим за MAPE Prophet (13.89%), підтверджуючи вищу точність.

Результат прогнозування навантаження досліджуваними моделями на основі патерну тижневих навантажень виглядає наступним чином:

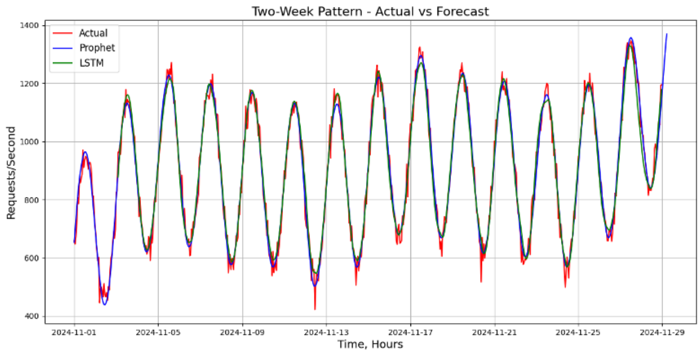

Рис. 4. Прогнозування моделей на основі тижневого паттерну.

Авторська розробка

Для більш плавного та сезонного патерну Prophet демонструє кращі результати за метрикою MAPE (2.98% проти 4.65%), що підтверджує її здатність враховувати сезонність. LSTM, хоча і має трохи вищий MAPE, показує менший RMSE (52.72 проти 104.09), що свідчить про меншу абсолютну помилку.

Таб. 4. Результат продуктивності моделей Prophet та LSTM для патерну тижневих навантажень.

Модель	**RMSE**	**MAPE (%)**
Prophet	104.09	2.98
LSTM	52.72	4.65

Авторська розробка

Для сценаріїв із різкими змінами навантаження, таких як On/Off Pattern, модель LSTM виявилася більш ефективною завдяки здатності враховувати нелінійні залежності у даних. У випадках із сезонними патернами, модель Prophet краще підходить для відносної оцінки прогнозу, але LSTM демонструє меншу абсолютну помилку. Вибір моделі для прогнозування слід здійснювати з урахуванням специфіки патерну навантаження та вимог до точності прогнозів.

Висновки

У цій роботі було проведено комплексне дослідження проактивного управління ресурсами у кластері Kubernetes із використанням методів штучного інтелекту для прогнозування навантажень. Дослідження підтвердило, що проактивний підхід є ефективним рішенням для забезпечення продуктивності та стабільності роботи додатків у динамічних хмарних середовищах. Аналіз існуючих механізмів управління, таких як Horizontal Pod Autoscaler (HPA) та Vertical Pod Autoscaler (VPA), виявив їхні суттєві обмеження, зокрема реактивний характер, що призводить до затримок у масштабуванні та ігнорування довготривалих трендів.

Запропоновано концепцію проактивного управління ресурсами, яка базується на прогнозуванні змін навантаження за допомогою алгоритмів машинного навчання. Цей підхід забезпечує завчасну адаптацію системи до змін, підвищує точність масштабування та мінімізує витрати на інфраструктуру. Експериментальне порівняння алгоритмів Prophet та LSTM показало, що LSTM є найбільш ефективною для сценаріїв із різкими змінами навантаження, тоді як Prophet демонструє кращі результати у випадках із сезонними коливаннями.

Оцінка моделей за допомогою метрик RMSE та MAPE підтвердила їх ефективність у різних сценаріях, що дозволяє адаптувати вибір алгоритму до специфіки завдань. Результати дослідження свідчать, що проактивне управління може бути інтегроване в Kubernetes через API для автоматизації масштабування на основі прогнозів, забезпечуючи підвищену стабільність і раціональне використання ресурсів.

Подальші дослідження будуть спрямовані на використання підходів підкріплювального навчання для вдосконалення прогнозів у реальному часі, інтеграцію додаткових метрик для підвищення точності оцінки стану системи та тестування розроблених рішень у масштабних реальних середовищах. Таким чином, впровадження проактивного управління ресурсами відкриває нові можливості для підвищення ефективності та економічності роботи хмарних середовищ, забезпечуючи стабільність і продуктивність сучасних обчислювальних систем.

KAPITEL 3 / *CHAPTER 3* [3]
RESEARCH OF THE PROCESS OF MAINTENANCE OF SOFTWARE SYSTEMS CODE

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Introduction

The quality of the software code directly affects the ability to scale and maintain the software for the long term. Scalability means the ability of a system to cope with an increase in workload or the integration of new functions without significant changes to its architecture. To achieve this, the software must be well structured and modular, allowing new components to be added or existing ones to be modified without negatively affecting other parts of the system. In terms of maintenance, supporting large-scale software systems can take up significant resources if the code is difficult to understand or difficult to modify. High-quality code reduces the time required to fix bugs or adapt the system to new conditions, which in turn reduces technical debt. Technical debt is the accumulated problems or outdated solutions that make it difficult to further develop the software. Low-quality code can quickly increase technical debt, forcing developers to spend more time and resources on fixing deficiencies, while high-quality code helps to avoid these problems, ensuring the stability and flexibility of the system in the long run.

Thus, the quality of software code is the foundation for effective software maintenance and scaling. Well-designed, tested, and documented code provides flexibility in making changes, increases system stability, and contributes to the long-term operation of the product. In modern software development, maintenance often takes up the majority of a project's time and budget—frequently exceeding the effort dedicated to initial development. This highlights the critical importance of investing in maintainability, as it ensures the system can adapt to evolving requirements, integrate new features, and sustain its performance over time.

Prioritizing code quality during development not only reduces maintenance costs but also minimizes technical debt, which can otherwise slow progress and increase

[3] ***Authors:*** *Zelenko Dariia, Gorbova Alexandra*

risks as the system grows. High-quality code supports more efficient debugging, testing, and enhancement processes, ensuring the software remains reliable and scalable during its whole lifecycle. By focusing on maintainability, organizations can achieve a robust foundation for innovation while maintaining a high standard of quality in their systems.

3.1. Analysis of the current state of the problem

Code maintenance and scalability have long been major challenges in software engineering, evolving as the complexity and size of software systems grows. Historically, early software systems were often developed in isolation, with limited attention to the durability or extensibility of the code base. However, in the second half of the 20th century, as computing needs expanded, the limitations of such approaches became clear. In the past, systems were often highly interdependent, poorly documented, and prone to failures when new features were introduced or when scaling was required to support a larger number of users or bigger datasets. These challenges highlighted the need for more structured approaches to ensure code quality, maintainability, and scalability. As a result, both academic research and industry practice began to place greater emphasis on these aspects, enabling the development of more stable, efficient, and resilient systems capable of handling growing demands and evolving requirements.

In this context, the book "Clean Code" [1] is an important milestone in the evolution of software engineering philosophy. Viewed through a scientific and historical lens, Clean Code contains many lessons learnt from decades of software engineering failures and successes. The book is not a revolutionary text in the sense of introducing completely new concepts, but rather a consolidation of best practices aimed at overcoming common pitfalls in code maintenance and scaling. It reflects the growing recognition, which began in the 1960s and 1970s, that software systems are not static objects. They must evolve, adapt and scale over time, and this requires a disciplined

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approach to coding that facilitates long-term maintenance.

From a scientific point of view, the need for maintainable and scalable code has been a subject of increasing study since the early days of computer science. Research in software engineering, especially in the areas of program analysis and code quality metrics, emphasizes that the structure and readability of code have a significant impact on its maintainability. The article [2] examines the limitations of current metrics like cyclomatic complexity and code readability. It argues that these measures often fail to capture nuanced improvements, such as those made during code refactoring. The study suggests enhancing metrics to better align with modern software practices and emphasizes their importance for maintainability and scalability.

Historically, the desire for easy-to-maintain and scalable code aligns with the development of agile methodologies in the late 1990s and early 2000s. Agile's focus on iterative development, customer collaboration, and rapid adaptation to change created a need for codebases that could be modified frequently without compromising code integrity. Clean Code fits neatly into this paradigm, offering guidelines for writing code that can be easily understood and modified by different developers working in short cycles. It reflects a broader movement in software development towards flexibility and adaptability, which was a response to the failures of the rigid, waterfall development processes that dominated previous decades. The article [3] emphasizes the importance of ensuring high code quality in the face of increasing complexity of software systems. The authors emphasize the need to apply the principles of Clean Code, which includes simplicity, readability and maintainability of the code. Even with modern technology and test automation, it is important to maintain clean code, as it promotes better team collaboration, reduces errors, and simplifies further support and scaling of programs. This allows you to create reliable software that can easily adapt to changing requirements and technologies.

The current state of the art of code maintenance and scalability remains a challenging issue in software engineering, despite the progress in development practices and tools. The scientific literature continues to explore this issue deeper, reflecting the growing complexity of software systems and the increasing demands for flexibility, performance, and reliability in the modern software development life cycle. Research on these topics addresses both the technical and cognitive factors that affect code maintenance and scalability, and there is recognition that despite decades of research, these issues persist in new forms as systems grow in size and complexity. The book [4] discusses the practice of refactoring as a key component of creating quality code. In particular, the analysis of code smells shows that clear identification of problematic code areas and their elimination at early stages can significantly reduce long-term support costs. The study [5] highlights that poor code quality makes it difficult to understand, increases task completion time, and leads to significant time wastage due to technical debt. It focuses on the link between code issues, such as code smells, and development team productivity. It is underlined that investments in maintaining code quality and eliminating technical debt can significantly increase development efficiency and reduce costs in the long run.

Modern research on code quality, writing and maintenance focuses on several key aspects related to the complexity of modern systems and the impact of this complexity on the costs and efficiency of developers. As the scale of systems and functionality requirements grow, the problem of maintaining code support becomes more and more difficult, prompting researchers and practitioners to search for new solutions. Modern researches emphasize that high-quality code not only ensures easy maintainability but also reduces overall development costs.

However, code review remains a challenging task due to its complex nature. Automated tools cannot take into account all contextual aspects [6], such as business logic or specific architectural decisions. This requires the integration of automated methods with manual checks and documentation improvements. An important aspect is the financial component of support.

In general, modern scientific research confirms that ensuring high-quality code writing and support requires a comprehensive approach. This includes improving automated tools, integrating them with human checks, implementing refactoring on a regular basis, and developing standards for complexity assessment. These efforts are critical to reducing costs and increasing team productivity in large projects.

3.2. The complexity of the development process

In the software lifecycle, maintenance is often the most resource-intensive phase, consuming a significant portion of the overall budget. Expanding software systems that become more complex due to interdependencies between components (functions, modules, objects) can result in code that is difficult to understand, modify, and test - driving up maintenance costs.

One of the main problems is that complexity often increases gradually during development. Initial design decisions or quick fixes implemented to meet deadlines or user requirements can lead to confusing structures. Such poorly designed systems, sometimes referred to as 'spaghetti code', make maintenance much more difficult. Developers tasked with maintaining such systems are often faced with the challenge of deciphering complex relationships between code elements, which increases the time and effort required for tasks such as bug fixes, feature updates and testing.

Another key challenge is that traditional engineering methods are not sufficient to deal with the arbitrary complexity natural to software systems. Unlike physical systems, where complexity is often predictable and natural, software complexity is highly abstract and can be unpredictable. This nature of software makes it prone to deterioration in structure as it evolves, unless constant efforts are made to simplify and refactor the code base. However, such efforts are often time-consuming and costly, which further increases maintenance costs.

Insufficient attention to maintainability at the beginning of the software development process results in systems that are difficult to extend or adapt to new requirements. This not only increases costs, but also reduces the overall reliability and performance of the system, as maintaining complex software increases the likelihood of new bugs. Complexity management therefore becomes a critical factor in ensuring the long-term sustainability and quality of software systems.

To study the problem, such concepts of mathematical statistics as finding a trend equation based on data from a study [7] analyzing the cost of developing various operating systems will be used.

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A trend equation is a mathematical model that describes how costs change over time (or with versions). All graphs are based on polynomial equations, and this model allows to take into account the acceleration of cost growth, not only linear or quadratic growth, but also more complex changes.

This will allow to qualitatively assess the costs of system development and its upgrades. Because the OS code consists of millions of lines that are responsible for the operation of various subsystems - from the kernel to drivers, file systems, network protocols and graphical interfaces. This multi-layered nature requires clear planning, especially in terms of support, modification, and functionality updates. Large projects of this type involve the development and use of sophisticated mechanisms for version control, testing, change management, and code metrics. In addition, such projects have large budgets due to their high criticality and long historical development.

3.3. Evolution of the growth in the cost of developing and supporting different versions of operating systems

Based on the research data, were built graphs of the ratio of estimated development costs and estimated support costs with an average value and trend lines for different OSes (Figures 1, 2, 3), trend calculated equations and final analytics performed.

Analyzing the graph, the following can be observed:

- Estimated development costs (billion USD), costs have been steadily increasing from Windows NT to Windows 8.
- Estimated maintenance costs (USD billion), with an even faster growth rate than development costs.
- Trend equation for development: $y = -0.0095x^6 + 0.2723x^5 - 3.0382x^4 + 16.806x^3 - 47.615x^2 + 70.725x - 27.111$. This function indicates a complex cost growth dynamic with certain periods of slowdown.

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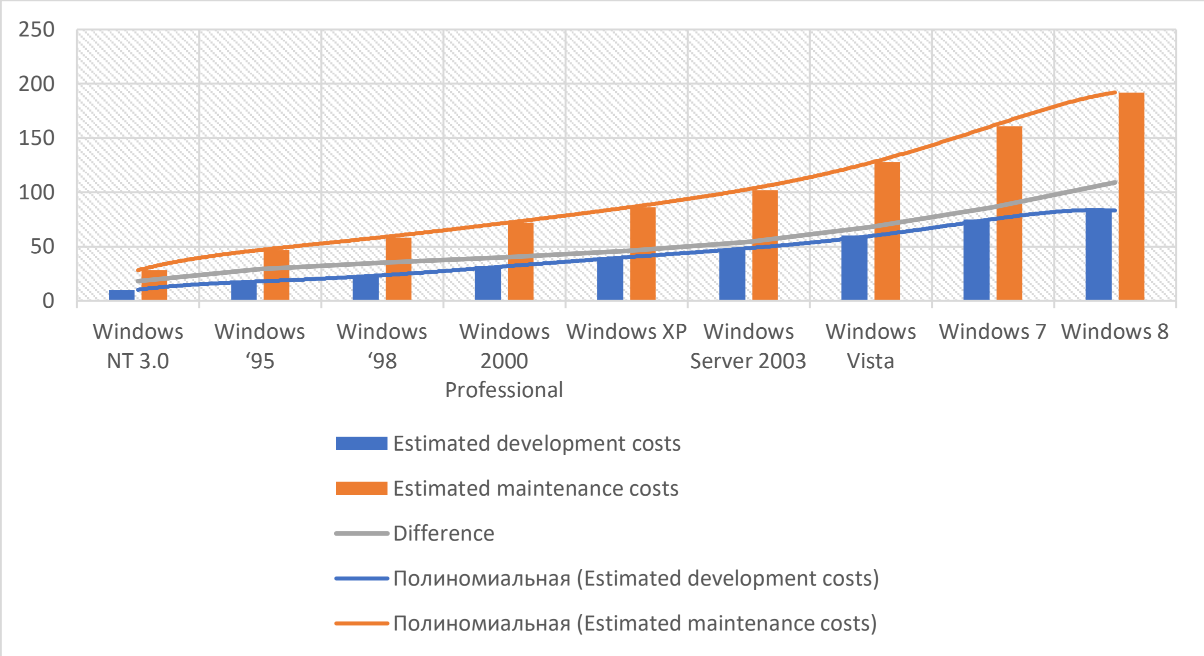

Figure 1 – Graph of the ratio of estimated development and support costs for different versions of Windows

- The trend equation for maintenance: $y = -0.0102x^6 + 0.2902x^5 - 3.2536x^4 + 18.575x^3 - 56.603x^2 + 98.934x - 29.889$. Maintenance costs show a similar but even greater growth rate.

Conclusion: Windows development and maintenance costs are significant, and maintenance takes up the bulk of the budget. The trend equations for development and maintenance costs show a complex nonlinear dynamic that includes periods of growth, deceleration and possible decline. Both equations have a polynomial structure of the 6th degree, which indicates significant variability over time. The development costs equation is characterized by an acceleration in the mid-term, but with a possible decline in the long run due to the negative impact of the high-degree coefficients. For maintenance, a similar pattern is observed, but with more intense growth, indicating a faster increase in expenditure in the medium term. Both processes indicate a complex variability in costs, with growth gradually slowing down in the later stages.

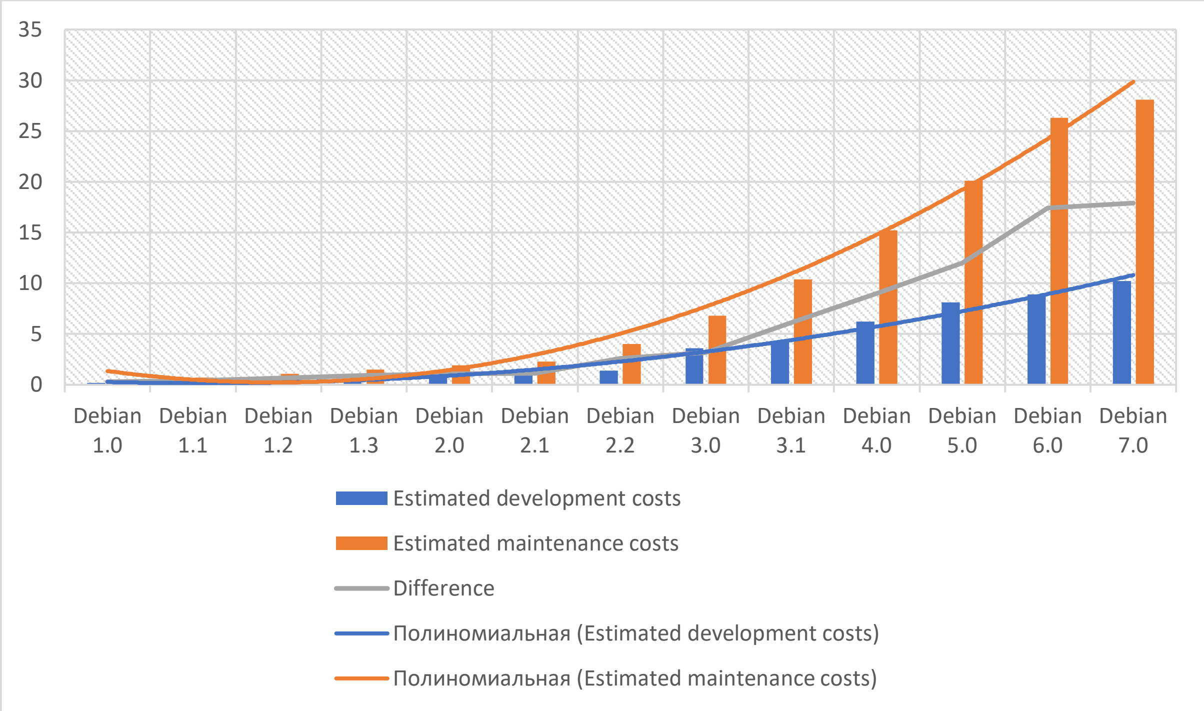

Figure 2 – Graph of the ratio of estimated development and support costs for different versions of Debian Linux

Analyzing the graph, the following can be observed:

- Estimated development costs (USD billion), with a gradual increase in these costs over time.
- Estimated maintenance costs (USD billion), these costs are significantly higher than development costs and have a significant growth rate.
- Trend equation for development: $y = 0.0903x^2 - 0.3857x + 0.5657$. This is a quadratic function, indicating an accelerated increase in costs in later versions of Debian.
- The trend equation for maintenance: $y = 0.2936x^2 - 1.7358x + 2.7993$. The quadratic function indicates a similar growth rate, but maintenance costs remain significantly higher.

Conclusion: the growth of development and maintenance costs is accelerating, with maintenance taking the dominant share. The trend equations for development and maintenance costs show a quadratic pattern of changes, indicating that costs are increasing at an accelerating rate with each new version of Debian. For development, the growth rate is moderate, with initial costs relatively low, but acceleration becomes more noticeable with increasing versions. In contrast, maintenance costs show a much higher baseline and faster growth rate, which highlights the greater complexity and amount of work required to ensure the stability and functionality of the system. This indicates that support becomes a major cost item in the long term, far outstripping development costs.

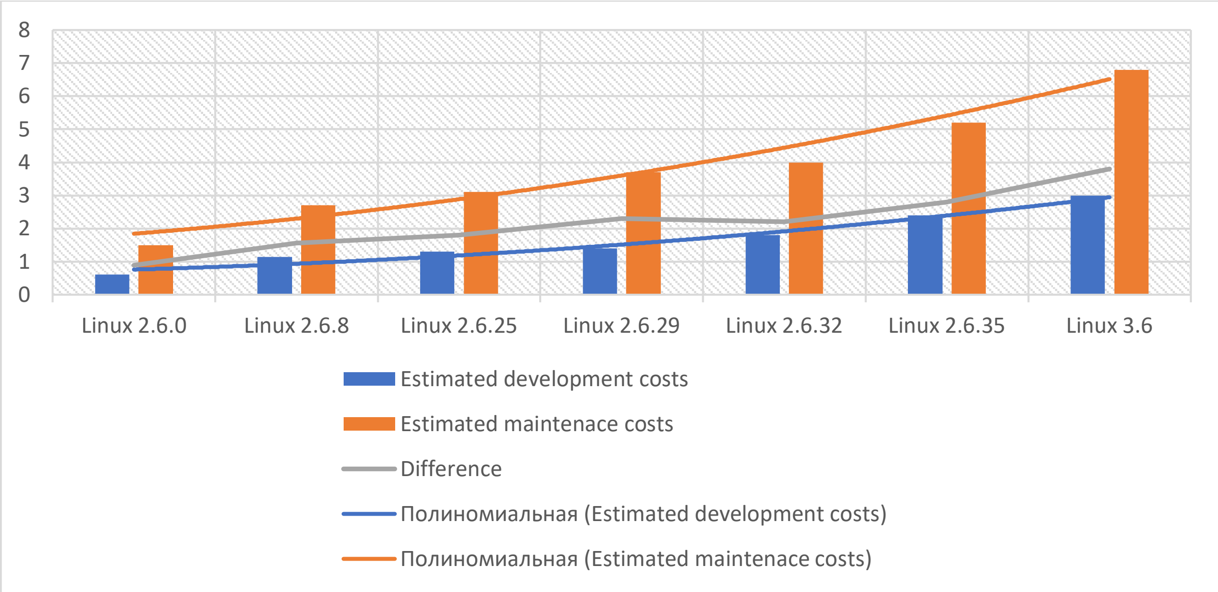

Figure 3 – Graph of the ratio of estimated development and support costs for different versions of the Linux kernel

Analyzing the graph, the following can be observed:

• Estimated development costs (billion USD). kernel development is gradually becoming more expensive with each version.

• Estimated maintenance costs (USD billion), although maintenance costs are increasing, they remain relatively low.

• Trend equation for development:$y = 0.0375x^2 + 0.0639x + 0.6586$. The quadratic function indicates a moderate but steady increase in costs.

• The trend equation for maintenance: $y = 0.0643x^2 + 0.2643x + 1.5143$. The growth in maintenance costs follows a similar trend.

Conclusion: Linux kernel development is showing a steady increase in costs, but in general, these costs remain lower than Debian or Windows. The trend equations for development and support costs show a quadratic relationship, indicating a moderate but steady increase in costs over time. Development costs are growing more slowly, indicating a relatively small increase in the volume or complexity of work as new versions are released. At the same time, support costs are growing faster, starting from a higher baseline, demonstrating their important role and the need for more resources. Both trends confirm the sustainability of costs with a gradual acceleration in the long term.

The equations confirm that development and maintenance costs increase not only proportionally with each version, but also with an increasing rate.

1.1.Dynamics of development and maintenance costs

- Development covers the initial investment in creating each version of a system or kernel. It is usually less expensive than maintenance, but increases over time.
- Maintenance is associated with the costs of support, upgrades, bug fixes and adaptation to changes in technology.
- For Windows, maintenance is growing faster than for Linux.
- In Debian Linux, maintenance is also growing rapidly, but a little slower than in Windows.
- With Linux Kernel, maintenance remains the least expensive.

Maintenance is a major cost element in the long term, especially for large operating systems (Windows and Debian).

1.2.Cost ratio

The difference between development and maintenance costs becomes more significant with each successive version:

- In Windows, this difference is particularly strong, reflecting the high cost of supporting a large ecosystem (with millions of users).
- In Debian Linux, the ratio is closer, but maintenance costs still exceed development costs.
- In Linux Kernel, development and maintenance costs remain close to each other, which indicates an efficient architecture.

Windows requires more investment at each stage than Debian or Linux Kernel, which indicates the complexity of its support.

1.3.Dynamics of polynomial trends

Polynomial equations show not just stable growth, but growth with acceleration.

- In Windows, you can see a sharp increase in costs in later versions (e.g. Windows 7 and 8).
- For Debian Linux and Linux Kernel, costs also increase with acceleration, but at a slower rate.

The most rapid growth in costs is observed in Windows, slightly less in Debian, and the most moderate in Linux Kernel.

1.4.Conclusions on cost-effectiveness

- Windows: Maximum costs due to the complexity of the system, its popularity and duration of support (Legacy systems).
- Debian Linux: Costs are rising, but the system remains cheaper than Windows due to the open source and community working on it.
- Linux Kernel: The most cost-effective, as costs grow the slowest, due to its narrow specialization and open approach.

Maintenance is a major expense for all systems. With each version, the costs increase rapidly, especially for Windows and Debian Linux.

The cost-effectiveness of the Linux Kernel is due to its openness and modular architecture, which reduces support costs.

For Windows and Debian, costs are increasing, but Windows leads the way in terms of total cost due to its higher support requirements.

Maintenance costs increase significantly with the size and complexity of the OSes in question. Also, as the complexity and size of the system increases, the proportion of effort devoted to maintenance steadily increases. While at the initial stages, about 60% of total effort is spent on support, at later stages of software development, this share can increase to 80% or more. This reflects the fact that maintaining large, complex systems requires more resources and time compared to initial development.

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Conclusions

The analysis of development and maintenance costs shows that maintenance is always more expensive than the initial development costs. This can be seen in all three projects: Windows, Debian Linux and Linux Kernel.

The main reasons are:

1. Duration of maintenance: Support for each version of the system lasts much longer than the development phase, which accumulates costs.

2. Expanding the user base: Increasing the number of users requires more resources for bug fixes, updates and adaptations.

3. Integration and compatibility: Over time, the number of external dependencies (software, hardware) increases, which increases the cost of maintaining stability and security.

The most prominent example is Windows, where maintenance costs dramatically exceed development costs due to the need for long-term support and the complexity of the ecosystem. For Debian Linux and Linux Kernel, the trend is the same, although maintenance costs grow more slowly, especially for Linux Kernel due to its modular structure.

Thus, maintenance costs are a determining factor in the overall cost of a system, and their growth is inevitable in the long run.

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KAPITEL 4 / *CHAPTER 4* [4]
ANALYSIS OF MODERN MANAGEMENT DECISION-MAKING STRATEGIES TO IMPROVE THE ENVIRONMENTAL EFFICIENCY OF RAILWAY INFRASTRUCTURE OPERATIONS

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Вступ

Залізничний комплекс має особливе стратегічне значення для України. Він є сполучною ланкою єдиної економічної системи, забезпечує стабільну діяльність промислових підприємств, своєчасне підвезення життєво важливих вантажів до найвіддаленіших куточків країни, а також є найбільш доступним для населення видом транспорту. Стійка робота залізничного транспорту забезпечує життєдіяльність та ефективний розвиток усіх галузей економіки країни.

Незважаючи на те, що залізничний транспорт визнаний у світі одним із найбільш екологічних видів транспорту, національний транспортний комплекс, що має порівняно з розвиненими країнами невисокі екологічні показники, зумовлені зношеністю технічних засобів, повільним впровадженням «зелених» інновацій.

Незважаючи, що частка забруднень невисока в процесі функціонування залізничного транспорту, є джерелом небезпеки, істотно впливає на навколишнє середовище, забруднює його і завдає шкоди. Розробка інструментарію управління розвитком системи природокористування на залізничному транспорті націлена на підтримку загальної зацікавленості у зменшенні забруднення та можливої шкоди навколишньому середовищу з метою забезпечення еколого-економічної безпеки країни. [1-4]

Основне завдання розвитку системи природокористування на залізничному транспорті нерозривно має бути пов'язане з головним завданням екології людини в цілому, основою якої є підтримка рівноваги всередині людства та зовнішнім світом, його середовищем. Це завдання може бути вирішене як у глобальному масштабі, так і на всіх територіальних рівнях. Кожен рівень її вирішення має свої

[4] ***Authors:*** *Kryachko Olexandr, Zelenko Yuliia, Solodiak Liliia*

особливості, характеризується певним набором обмежень, можливостей та методів для досягнення мети.

Управління природокористуванням знаходиться у сфері підвищеної уваги з боку влади, бізнесу та суспільства. Окремі елементи мають різний ступінь розвиненості та практичної реалізації. Еколого-економічний аналіз дає можливість визначити, які з інструментів, що діють, слід визнати малоефективними і які стимулюючі системи можна вважати найбільш перспективними.

Подальший розвиток економічного механізму природокористування має ґрунтуватися на: 1) оцінці ефективності діючих елементів економічної системи у стимулюванні раціонального природокористування; 2) розроблення спеціальних елементів економічного механізму, що стимулюють збереження довкілля людини, законодавчому та нормативно-методичному забезпеченні їх функціонування; 3) подальшому впровадженні та розвитку системи екологічного менеджменту на вітчизняних підприємствах.

Розвиток екологічного менеджменту тісно пов'язане із пріоритетами внутрішньої та зовнішньої політики держави. Вони, у свою чергу, мають забезпечувати природо- та ресурсоохоронні інтереси держави, а також сприяти зміцненню економічних позицій національних товарів на світових ринках екологічно чистої продукції.

При цьому очевидною є необхідність підвищення достовірності інформації про функціонування різних блоків економічних регуляторів саме у сфері управління природокористуванням на об’єктах залізничного транспорту.

4.1. Аналіз специфіки впливу залізничного транспорту на навколишнє середовище

Характер впливу транспорту на навколишнє середовище визначається складом техногенних факторів, інтенсивністю їх впливу, екологічною вагомістю

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впливу на елементи природи. Техногенний вплив може бути локальним від єдиного фактора або комплексним - від групи різних факторів, що характеризуються коефіцієнтами екологічної маси, які залежать від виду впливу, їх характеру, об'єкта впливу.

Для оцінки рівня впливу об’єктів транспорту на екологічний стан природи використовують такі інтегральні характеристики:

- абсолютні втрати навколишнього середовища;
- компенсаційні можливості екосистем;
- небезпека порушення природного балансу, виникнення неочікуваних збитків;
- рівень екологічних втрат, викликаних впливом об'єктів транспорту на навколишнє середовище та локальних екологічних зрушень.

В даний час на долю залізничного транспорту приходить 77% вантажообігу і 40% пасажирообороту транспорту загального користування. Такі обсяги робіт пов'язані з великим споживанням ресурсів і, відповідно, викидами забруднюючих речовин у біосферу. Вплив залізничного транспорту на екологічну обстановку вельми значний. Він сприяє, перш за все, забрудненню повітряного, водного середовища та літосфери, а також відчуженню земель при будівництві та експлуатації залізничних колій [6].

Крім викидів продуктів згоряння палива, щорічно при перевезенні і перевантаженні вантажів з вагонів в навколишнє середовище потрапляє велика кількість небезпечних речовин. Більше 20% розвернутої довжини залізничних ліній мають значний ступінь забруднення від штатних втрат вантажів. Під час зупинки поїздів з букс колісних пар виливаються рідкі змащувальні матеріали. Із вагонів-цистерн на коліях та у міжколійному просторі, під час перевезень, внаслідок не герметичності клапанів і зливних приладів цистерн, через нещільність люків втрачаються нафтопродукти. Вони потрапляють через ґрунтові горизонти і забруднюють підземні води.

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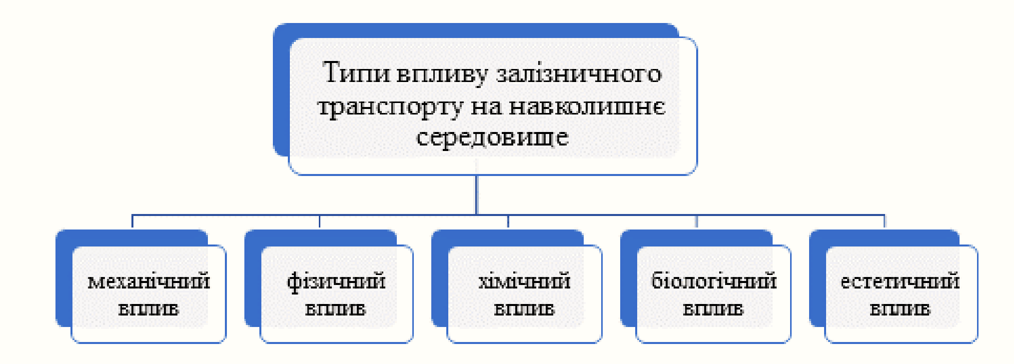

Рисунок 1 - Типи впливу залізничного транспорту на навколишнє середовище.

Фактори (фактори) впливу об'єктів залізничного транспорту на навколишнє середовище (рис. 1) зазвичай класифікують за такими визначеннями:

- механічні (тверді відходи), механічний вплив на ґрунти будівельних, дорожніх та інших машин;

- фізичні (теплові ізоляції, електричні поля, електромагнітні поля, шум, інфразвук, ультразвук, вібрація, радіація та ін.);

- хімічні речовини та сполуки (кислоти, щілини, солі металів, альдегіди, ароматичні вуглеводні, краски та розчинники, органічні кислоти та сполуки та ін.), які підрозділяються не надзвичайно небезпечні, високо небезпечні, небезпечні та мало небезпечні;

- біологічні (макро- і мікроорганізми, бактерії, віруси);

- естетичні (зміна та деструкція ландшафтів).

Ці фактори можуть діяти на природне середовище довго, порівняно недовго, короткочасно і миттєво.

Час дії факторів не завжди визначає розмір шкоди, що завдається природі. За масштабами дії шкідливі фактори розподіляються на: діючі на невеликих площах, діючі на окремих ділянках місцевості та глобальні.

Хімічні речовини і сполуки можуть мігрувати і розсіюватися в повітрі, у воді, ґрунтах, наносячи зворотний, частково зворотний і незворотній збиток довкіллю. У процесах міграції хімічних речовин і мікроорганізмів важливе місце займає транспорт.

Основними напрямками зниження кількості забруднень навколишнього середовища є раціональний вибір технологічних процесів для виробництва готової продукції та її транспортування; використання засобів захисту навколишнього середовища та підтримання їх в справному стані.

Особливу тривогу з точки зору екологічної безпеки викликає перевезення небезпечних вантажів. До небезпечних вантажів відносяться речовини та вироби, які в силу своїх властивостей та особливостей при екстремальних обставинах у процесі переміщення або зберігання можуть завдати шкоди навколишньому середовищу, викликати вибух, пожежу або пошкодження транспортних засобів, пошкоджень, а також гибель, травмування, отруєння , захворювання людей або тварин.

4.2. Методи визначення результативності роботи транспортної галузі

Перевезення товарів та пасажирів транспортними засобами завжди пов’язане з використанням ресурсів та з негативним впливом на довкілля. Дані про пробіг транспорту є хорошим непрямим показником кількості та часового розвитку впливів на довкілля, особливо дорожнього транспорту. Ці дані відсутні або не публікуються в офіційній українській статистиці.

Іншим корисним показником результативності транспорту, який в більшості виражається у кількості вантажів (тон) або пасажирів та відстанях перевезення (км). Показник результативності транспорту включає модальний розподіл, який показує внесок різних видів транспорту (з їх різними рівнями впливу на довкілля) у загальну результативність роботи транспорту. Напрямки показників результативності роботи транспорту та модальний розподіл є важливими показниками для розвитку впливу на довкілля, спричинене транспортом [6].

Разом з тим, в Україні тільки починається усвідомлення того, що екоаудит є необхідною за міжнародними стандартами передінвестиційною стадією оцінки ризиків, обов'язковою процедурою оцінки вартості підприємств, що приватизуються, для вирішення проблем екологічного життя, екологічно чистої продукції. Ринок диктує попит на екологічний аудит. Позитивно сертифікована після екоаудиту продукція та послуги користуються більшим попитом, а її виробники, крім того, отримують від держави і банків низку пільг.

Таким чином, ухвалення управлінського природоохоронного рішення супроводжується виникненням проблеми переходу об'єкта в інший стан з урахуванням суспільної думки. Від чіткої та правильної постановки завдання залежить те, наскільки правильне рішення буде ухвалено керівником. При цьому, класифікація проблеми носить завжди суб'єктивний характер і залежить від поєднання об'єктивних обставин та індивідуальних особливостей особи, яка приймає рішення.

Довгостроковий аналіз природоохоронних інвестицій в основний капітал показує, що напрями інвестування транспортних підприємств ранжуються за рівнем зменшення вкладених коштів у такому порядку:

1. Охорона та раціональне використання водних ресурсів;

2. Рекультивація земель;

3. Охорона атмосферного повітря;

4. Охорона навколишнього середовища від шкідливого впливу відходів виробництва та споживання.

Дуже важливо розуміти, що збори від стягування екологічних податків дозволяють повсюдно використовувати спеціальні режими оподаткування та надавати преференції малому та середньому бізнесу, підприємствам громадського транспорту та іншим секторам громадського обслуговування та соціального призначення. [7]

Крім того, диференціація податкових ставок може бути стимулом технологічної модернізації та екологізації підприємств. Водночас слід зазначити ще одну тенденцію. Високе співвідношення екологічних податкових надходжень від загального оподаткування не обов'язково є ознакою високого пріоритету охорони навколишнього середовища.

Таким чином, впровадження стратегії розвитку залізничного транспорту передбачає здійснення конкретних дій, визначених у вигляді здійснення її виконання. Контроль реалізації стратегії забезпечує зворотний зв'язок, що дозволяє коригувати поставлені цілі та завдання розвитку залізничного транспорту як сталої еколого-економічної системи. Необхідність контролю обумовлена трансформацією довкілля, появою нових можливостей.

Аналіз елементів структури стратегічного управління залізничним транспортом як економічної системою дозволяє зробити висновок про орієнтацію цього виду управління на досягнення позиції, яка забезпечить ефективне функціонування цієї галузі в умовах, що змінюються. Загальні напрями стратегічного управління залізничним транспортом подано на рис. 2.

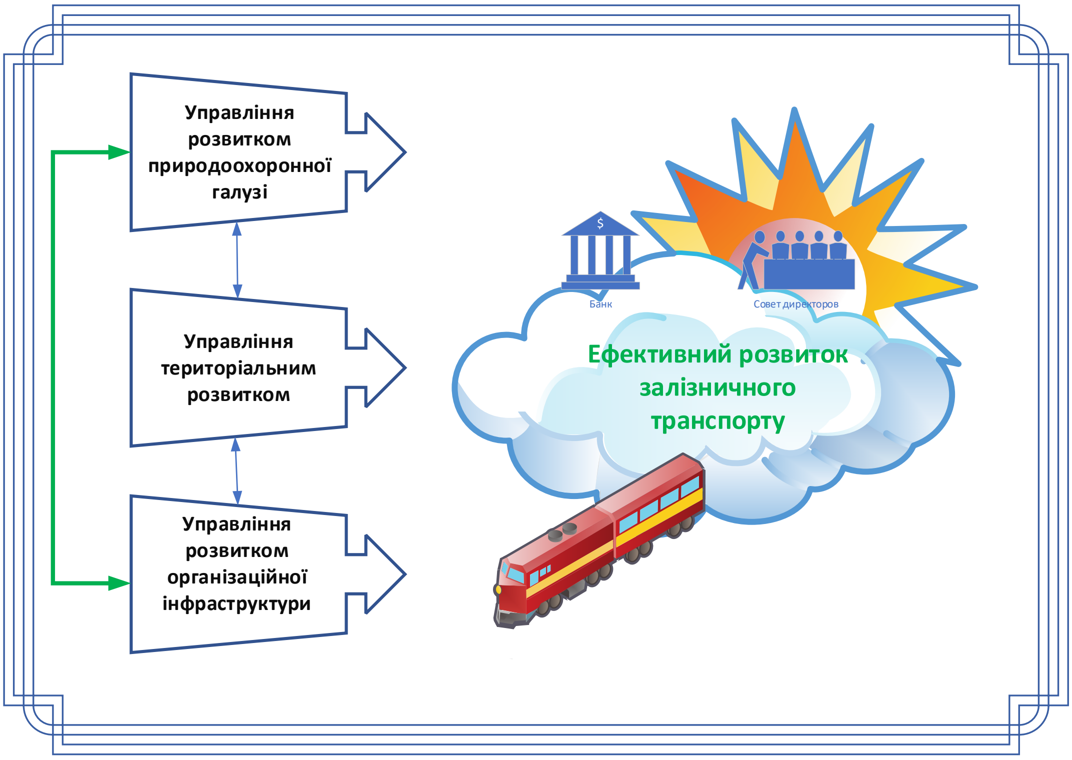

Рисунок 2 - Загальні напрямки стратегічного управління залізничним транспортом

4.3. Принципи визначення еколого-економічної результативності

Вирішення екологічних проблем можливе лише у взаємозв'язку з економікою. За допомогою економічних важелів можна зацікавити підприємства та організації до освоєння й використання мінеральних ресурсів, створення безвідхідних технологій та розробки ресурсозберігаючих технологій.

В цілях забезпечення ефективності заходів щодо попередження і ліквідації негативних наслідків повинен існувати комплекс нормативних документів, що регламентує діяльність підприємств.

До основних критеріїв еколого-економічної ефективності природоохоронних заходів, що дозволяють враховувати зовнішні та соціальні ефекти, належать:

- включення екологічних витрат і вигод у грошові потоки, що враховуються під час аналізу заходів та моделювання грошових потоків;

- облік фактору часу як одного з інструментів для відображення довгострокових екологічних та соціальних наслідків реалізації природоохоронних заходів;

- моделювання сурогатних ринків для визначення цінності та вартості природних благ, ринки яких відсутні або нерозвинені;

- виключення ризику подвійного обліку витрат та переваг;

- облік можливості недооцінки екологічних переваг та природних благ в аналізі через відсутність даних, складнощів з їх отриманням та опис даних переваг та благ у якісних показниках;

- гнучкий вибір методів та методик розрахунку, що виходить з наявності методик, що підходять для оцінки наслідків певного типу впливу та їх доцільності, наявності вихідної інформації, часу проведення аналізу та наявних фінансових ресурсів;

- порівняння соціально бажаних результатів та приватних інтересів для аналізу можливості усунення суперечностей, що виникають, на ранніх стадіях прийняття рішень та аналіз розподілу переваг і витрат між різними сторонами.

- Використання аналізу «витрати - ефективність» при недоцільності або неможливості проведення традиційного аналізу «витрати-вигоди», наприклад у випадках, коли вигоди уявити в грошах неможливо.

З метою визначення еколого-економічної ефективності природоохоронної діяльності проводиться оцінка природоохоронних заходів, оцінка існуючої екологічної обстановки та системи благоустрою міських ландшафтів. Існує кілька видів еколого-економічних оцінок природоохоронної діяльності:

- оцінка шкоди: завданої, поточної, потенційної (можливої);
- оцінка податкових, компенсаційних та штрафних платежів за забруднення, транзакційних витрат;
- оцінка операційних та капітальних витрат: на ліквідацію завданих збитків та на попередження потенційної шкоди;
- оцінка результатів: отримання товарної продукції та утилізованих вторинних матеріальних ресурсів, витрат на очищення та «вкладання» в навколишнє середовище вторинних відходів.

Як основні критерії оцінки еколого-економічної ефективності природоохоронної діяльності рекомендується використовувати такі показники як: чиста наведена вартість; внутрішня ставка віддачі; співвідношення витрат та переваг.

Структура оцінки ефективності діяльності підприємств залізничної галузі в аспекті відповідальності представлена рисунку 3.

Підвищення ефективності управління практично дорівнює зростанню ефективності управлінських природоохоронних рішень на всіх рівнях, оскільки прийняття рішень є основним інструментом керуючого впливу; саме в розробці, прийнятті, організації та контролі виконання рішень полягає діяльність як окремих менеджерів, так і апарату управління загалом. Однак, завдання визначення ефективності управлінських природоохоронних рішень належить до найбільш складних і спірних проблем управління і потребує вирішення.

Чинники, що впливають прибуток підприємства, представлені на рисунку 4. Ступінь впливу вищезгаданих факторів залежить не тільки від співвідношення їх самих, а й від стадії життєвого циклу підприємства, від компетенції та професіоналізму його фахівців.

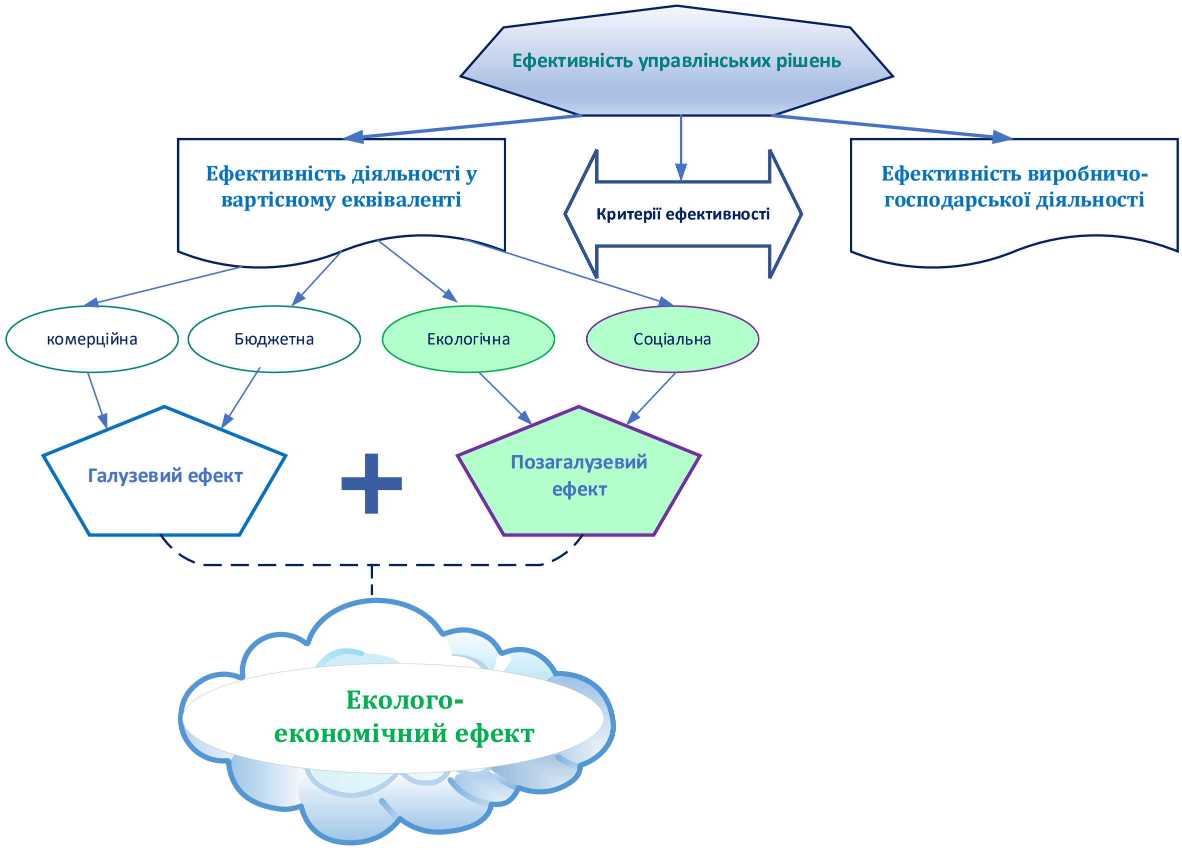

Рисунок 3 - Складові оцінки ефективності на підприємствах залізничного транспорту з позиції скорочення неочікуваних збитків.

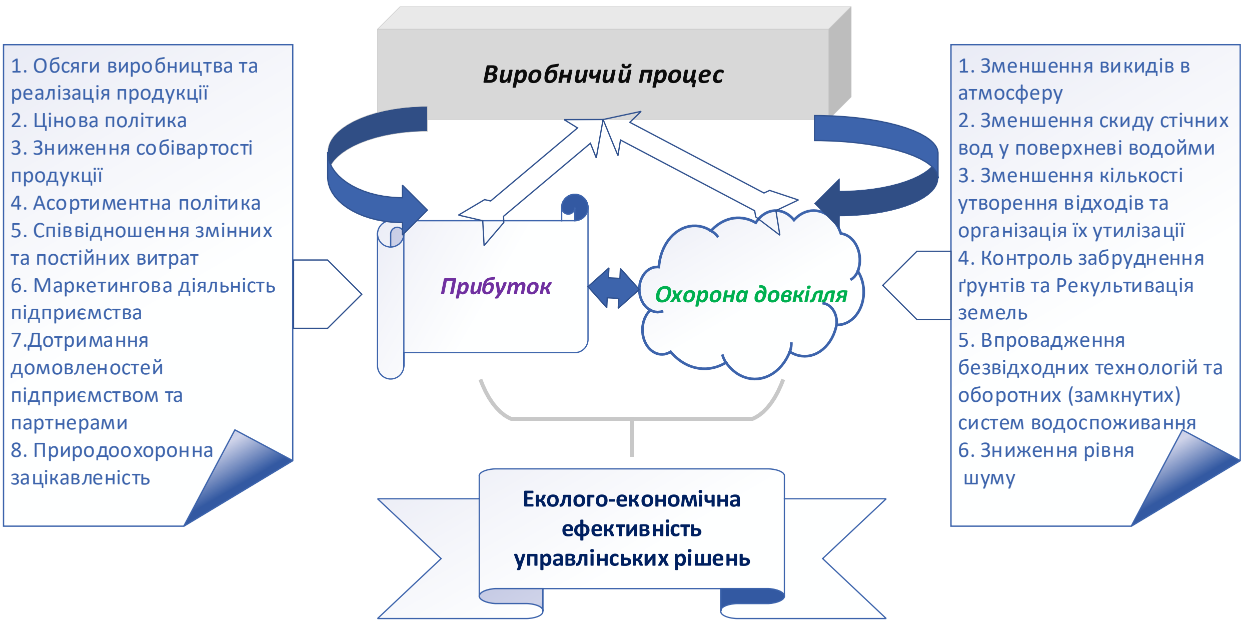

Рисунок 4 - Чинники, що впливають на еколого-економічну результативність підприємства.

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Практика показує, що вплив окремих чинників кількісно оцінити майже неможливо. Наприклад, репутація підприємства, тобто сформована думка про підприємство, що витікає з різних аспектів (рівень якості обслуговування, збереження природничого потенціалу, потенційні можливості, тощо).

4.4. Порядок організації системи управління процесами природокористування

У всіх сферах економіки важливою є оцінка реальних величин еколого-економічних збитків: для оцінки загальної економічної ефективності регіональної економіки, для відбору інвестиційних проектів всіх видів, зокрема проектів природоохоронного призначення, для реалізації принципів екологічного страхування та ін.

Адекватна оцінка реальних величин еколого-економічних збитків необхідна не тільки для забезпечення оптимального функціонування транспорту, але і у всіх сферах економіки: для оцінки загальної економічної ефективності регіональної економіки, для відбору інвестиційних проектів всіх видів, зокрема проектів природоохоронного призначення, для реалізації принципів екологічного страхування і так далі.

Специфіка оцінки еколого-економічної ефективності природозахисних заходів визначається особливим характером результату їх проведення і функціонування. Вони призначені для запобігання або зменшення збитку, що викликається небезпечними процесами. У зв'язку з цим стає необхідним доповнення їх рекомендаціями щодо обліку і оцінки попередженого збитку.

Оцінка економічної ефективності природоохоронних витрат має особливості, що виявляються у відмінностях видів ефекту, а також у методах їх визначення.

Відповідно до стандартної методики розрізняють первинний та кінцевий комплексний соціально-економічний ефект від заходів щодо захисту навколишнього середовища.

Первинний ефект полягає у зниженні забруднення навколишнього середовища та поліпшенні його стану та проявляється у зниженні обсягів забруднень та концентрації шкідливих домішок в атмосфері, водному середовищі та ґрунті. Враховуючи необхідність поєднання економічних та екологічних інтересів підприємства, первинний ефект слід висловлювати безпосередньо у вигляді збільшення продукції, випущеної без порушення екологічних норм.

Кінцевий економічний ефект виявляється у підвищенні ефективності виробництва. При цьому економічні результати виявляються як приріст чистої продукції, зниження втрат сировини та матеріальних ресурсів, економія витрат у невиробничій сфері, зниження витрат із власних коштів.

Кінцевий соціальний ефект проявляється у зниженні захворюваності населення, покращенні умов відпочинку, збереженні природних ресурсів, що мають естетичну цінність.

Абсолютна ефективність витрат із захисту довкілля визначається виявленням економічної результативності природоохоронних заходів різних рівнях господарювання (країна, регіон, галузь, місто, підприємство).

Отже, для розробки перспективної стратегії підвищення екологічних показників залізничної інфраструктури необхідним першочерговим завданням є чітке формулювання екологічної політики, що узгоджується з вимогами системи екологічного менеджменту згідно ISO 14001.

При цьому, перелік основних заходів щодо зниження еколого-економічного ризику на підприємствах залізничного транспорту можна систематизувати за типами призначення (табл. 1).

При розрахунках економічних витрат та ефекту від запланованих природоохоронних заходів на тривалу перспективу слід враховувати фактори, які можуть вплинути на ці величини. До них відносяться:

- підвищення вимог до якості довкілля;

- зміна стану навколишнього середовища, що викликаються зростанням

Таблиця 1 - Класифікація заходів щодо зниження еколого-економічного ризику на підприємствах залізничного транспорту.

Призначення	Тип заходу	Опис заходів
Скорочення викидів забруднюючих речовин у атмосферне повітря	Ліквідація джерел викидів	Закриття неефективних котельних та підключення об'єктів до централізованого або комплексного джерелам тепла
	Впровадження ресурсозберігаючих технологій	Переведення котельних, ковальських, ливарних цехів та термічних відділень
	Монтаж та наладка пилогазоуловлюючого обладнання	Впровадження, модернізація та поточний ремонт пилогазоуловлюючого обладнання у технологічних процесах (сушка піску, метало- та деревообробка)
Зменшення скидів забруднюючих речовин у поверхневі водні об'єкти	Ліквідація джерел скидів	Підключення стоків до каналізаційних систем, передача очисних споруд до муніципальної власності
	Впровадження ресурсозберігаючих технологій	Впровадження оборотних, циклічних та замкнутих систем водоспоживання, переведення технологічних процесів на безводні технології
	Монтаж, реконструкція та наладка очисних споруд	Впровадження, модернізація та поточний ремонт систем вовдовідведення та очищення стічних вод
Зменшення кількості утворення відходів, їх знешкодження та утилізація	Зменшення кількості утворення відходів	Ліквідація малопотужних неефективних котелень, переведення котелень на екологічні види палива
	Знешкодження відходів	Впровадження технологій термічного знешкодження нафтошламів та нафтовідходів з утилізацією тепла та очищенням викиду; очищення ґрунтів, забруднених нафтопродуктами і фенолами за допомогою біотехнологій
	Утилізація відходів	Регенерація та повторне використання відпрацьованих олив та мастил та інших технологічних рідин, що підлягають регенерації; виготовлення паливних брикетів з відходів деревини

виробництва, проведенням комплексу природоохоронних заходів;

- зміна вартості будівельно-монтажних робіт та обладнання;

- розвиток науки і техніки, створення нових технічних засобів та технологій, що зменшують негативний вплив виробничої діяльності на навколишнє середовище;

- зростання обсягу виробленої за одиницю робочого дня чистої продукції чи іншого показника обсягу продукції, яким обчислюється продуктивність праці;

- збільшення відносних розмірів коштів, що виділяються на охорону здоров'я, соціальне страхування та соціальне забезпечення;

- підвищення економічної цінності мінерально-сировинних, земельних, лісових та інших ресурсів. [3]

Висновки

Для розробки перспективної стратегії екологізації залізничної інфраструктури, як і для більшості інших господарських підприємств необхідним стає акцент на попередження небажаних еколого-економічних наслідків, отже зниження еколого-економічного ризику, при цьому:

1. Найважливішими передумовами переходу до екологічно чистих виробництв, виступають чинники розвитку найкращих доступних технологій, підвищення комплексності використання природного сировини, збільшення обсягів виробничого використання та реалізації утворюються відходів.

2. Дослідження впливу основних факторів на процес організації екологічно чистих виробництв дозволить встановити критерії та показники еколого-економічної ефективності виробництва та розробити рекомендації для запровадження їх у практику оцінки ефективності виробництва. Зокрема, доповнити систему показників оцінки екологоекономічної ефективності виробництва зведеним та приватними індексами.

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KAPITEL 5 / CHAPTER 5 [5]
A COMBINATORIAL MATHEMATICAL MODEL OF THE DYNAMICS OF THE INCIDENCE OF COVID-19 ON THE EXAMPLE OF THE SITUATION IN THE UKRAINE

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Вступ

Життя людини беззаперечно є найбільшою цінністю. Важливою частиною його основ являється стан здоров'я людей. Однією із загроз життю та здоров'ю людства на поточний момент є масштабні епідемії та пандемії, викликані гострими респіраторно-вірусними інфекціями (ГРВІ), до яких за ознакою локалізації шляхів потрапляння до організму та первинного зараження людини можна віднести такі небезпечні інфекції, як коронавірусна, грип та інші подібні гострі захворювання. Усвідомлення механізмів їх передачі та динаміки захворюваності є ключем до аналізу та прогнозу дієвості протиепідемічних заходів, поводження людини в умовах пандемії, керування та стабілізації рівнів захворюваності, наукового обґрунтування заходів з мінімізації шкоди, заподіяної інфекцією. Таким чином, задача розробки науково обґрунтованих математичних моделей розповсюдження ГРВІ являється важливою та життєво актуальною, тому цій проблемі присвячена велика кількість праць ближнього і дальнього зарубіжжя [6-14]. Метою роботи є створення науково обґрунтованих математичних моделей динаміки розповсюдження ГРВІ та проведення первинних етапів аналізу та верифікації розроблених математичних інструментів.

Об'єктом дослідження є офіційна статистика (рисунок 2) захворювання на COVID-19 [2] населення України в період пандемії 2020-2021 рр.

5.1. Методика

Прогноз розвитку небезпечних інфекцій є життєво важливим, тому було

[5] ***Authors:*** *Horobets Volodymyr, Sablin Oleg, Zelenko Yuliia*

виявлено достатню кількість спроб адекватного опису досліджуваних процесів.

Мови про моделювання конкретних більших епідемій у математичній теорії епідемій до недавнього часу майже не було [3]. Це наочно показав організований ВООЗ (Всесвітньою організацією охорони здоров'я) у листопаді 1970 р. Міжнародний симпозіум по кількісній епідеміології. На цьому симпозіумі були представлені, по суті, всі країни, що займаються теорією епідемій: США, Англія, Франція, ФРН, Японія, Канада та ін. У доповідях радянських учених були наведені результати по моделюванню майже 100 спалахів грипу в найбільших містах СРСР (рисунок 1).

Ідею використання принципів механіки суцільних середовищ [3] пропонувалося використовувати для побудови не тільки епідемічної динаміки, але і єдиного підходу до широкого кола медико-біологічних і медико-соціальних завдань, Постараємося сформулювати в постановку такого завдання. Нехай у кожному індивідуумі популяції *P* протікає безперервний медико-біологічний процес, для виміру якого прийняті величини φ_1, φ_2, φ_3, ..., ..., φ_n. Їхня сукупність називається станом індивідуума. Нехай величина *f* достатня для детермінованого опису процесу, тобто наступний стан індивідуума визначається попереднім, а саме:

$$\frac{d\varphi_i}{dt} = f_i(\varphi_1, \varphi_2, \dots, \varphi_n), \quad i = 1, 2, \dots, n. \tag{1}$$

Ці рівняння в певній мірі можна розглядати як модель процесу в індивідуумі. Будемо називати їх також рівняннями руху частки. Автору статті здається, що вказані рівняння мають всі ознаки моделі аналізу-прогнозу, викладені в статті [4], яка автоматично настроюється на збіг з базою вихідних даних та є адаптивним алгоритмом. Вид функцій f_i може бути всілякий і залежати від конкретних завдань. Відсутність t у правих частинах системи означає однорідність часу стосовно досліджуваного процесу. Структура fi може містити й вплив, що міняється згодом, наприклад лікування. Помітимо, що не слід змішувати незалежність функцій f_i від часу з тими випадками, коли відбувається масовий вплив на популяцію, обумовлений календарним часом, скажемо, здійснення за графіком яких-небудь медико-біологічних заходів. Подібна ситуація буде враховуватися іншими рівняннями, а рівняння (1) зіставляється з окремим індивідуумом. Нехай кожному індивідуумові відповідає частка, що його представляє, та безупинно рухається у фазовому просторі. Тоді система дає рівняння траєкторії окремої частки, а вектор, певний правими її частинами, - стаціонарне поле швидкостей у просторі для всього потоку. Даний механістичний підхід дозволив отримати достатньо непогану збіжність на рівні тижневих флуктуацій захворюваності, але, на жаль, не встановлює загальних тенденцій розвитку епідемії в цілому.

В роботі [5] наведено основні положення системи прогнозування епідемій грипу на території СРСР.

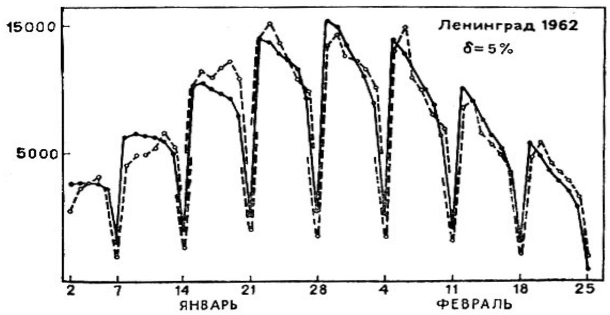

Рисунок. 1 - Моделювання розвиту епідемії грипу в СРСР.

Вона складалася (на 1971 р.) з чотирьох підсистем:

1) ВЦГ(Всесоюзний центр з грипу);

2) обчислювальний центр із використанням ЕОМ ЄС 1022, пізніше ЕОМ ЄС 1032;

3) автоматизована база даних із можливістю оперативного й ретроспективного епідеміологічного аналізу інформації;

4) комплекс програм для ЕОМ моделювання і прогнозування епідемій грипу.

Звичайно, найбільший інтерес представляла б четверта підсистема, але наслідуючи загальноприйняту в Радянському Союзі політику приховування інформації, верифікація підсистеми в статті обмежується думкою з цього приводу академіків Глушкова і Гнеденка.

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В науковій праці [6] колективом авторів Інституту обчислювальної математики та математичної геофізики РАН РФ, Математичного центру Академмістечка та Новосибірського державного університету (Росія) зокрема зроблено огляд сучасних уявлень та математичних систем моделювання розвитку епідемій.

Розглянемо ці моделі детальніше. У відповідності до [7] існує чотири базові моделі:

- **SIRS:** .Сприйнятливі > Інфіковані > Видужалі > Сприйнятливі. (Модель для опису динаміки захворювань с тимчасовим імунітетом).

- **SEIR:** .Сприйнятливі > ті, що контактували з інфекцією (Exposed) > інфіковані > видужалі. (Модель для опису поширення захворювань із інкубаційним періодом).

- **SIS:** .Сприйнятливі > інфіковані > сприйнятливі. (Модель для поширення захворювання, до якого не виробляється імунітет).

- **(MSEIR):** .Наділені імунітетом від народження (Maternally derived immunity) > сприйнятливі > ті, що контактували з інфекцією (Exposed) > інфіковані > видужалі.. Модель, що враховує імунітет дітей, придбаний внутрішньоутробно.

Математичні моделі,які реалізують циклічні послідовності станів спільнот при епідеміях, складаються з 5-7 диференційних рівнянь. При необхідності, наприклад, відпрацювання керування перебігом епідемії, вони доповнюються цільовими функціями у вигляді диференціальних рівнянь або функціоналів. Нажаль, як видно з даних, наведених в роботі [6], спроба отримати точну оцінку перебігу епідемії, включно короткочасні (тобто високочастотні зміни) флуктуації, не можна вважати надто вдалими.

З початком пандемії COVID-19 закономірно виникла ідея застосувати розроблені раніше моделі поширення ГРВІ (наприклад, грипу). Отож, внаслідок актуальності проблеми, публікуються наукові праці, пов'язані з моделюванням та прогнозуванням розвитку пандемії [17-22]. Традиційно використовуються системи нелінійних звичайних диференційних рівнянь (ЗДР) різного (три [17] і більше, до 11 [18]) порядку доповненні функціональними залежностями змінних в рамках застосованої системи поглядів на явище або відповідної бази знань. Найбільш застосовною удається математична модель з системи 9 диференційних рівнянь [20-22].

В роботах, присвячених проблемі пандемії COVID-19 найбільш часто вирішуються проблеми динаміки поширення інфекції, переважно в окремих державах [22-22] або відокремлених територіях. Трапляються питання стримування інфікування населення [21], моделювання перебування людей [18] в різних станах згідно моделей перебігу захворювання .

Однак зауважимо, що підвищення складності математичних моделей робить їх менш керованими та спостережними. Тому отримані прогнози впливу окремих параметрів на перебіг пандемії можуть виявитися менш адекватними із ростом складності математичної моделі.

Слід прийняти, що кожен випадок зараження породжує логічну послідовність пов'язаних з ним подій (інкубаційний період, активна фаза захворювання, одужання або загибель) з оцінюваними статистично характеристиками. Тоді, якщо певним чином нам відома функція кількості інфікованих людей від часу, наслідки цих заражень в середньому визначаються повністю детерміністичним підходом.

Запропонована в цій роботі математична модель складається з одного рівняння приросту головного показника – денної кількості знов інфікованих (рівняння, подібне ЗДР), поточне значення функції якого від часу ініціює певну послідовність логічних станів, відповідних побудованій статистично моделі, наприклад SIRS. Пропонована математична модель фактично містить єдиний основний параметр - середню вірогідність передачі інфекції. Це робить маловірогідними помилки, пов'язані з визначенням численних параметрів, їх функціональних властивостей і взаємодії в моделі.

Взагалі, намагання отримати найкращу збіжність моделі з натурними даними «в деталях» дуже часто провокує гіршу збіжність моделі в віддалених тенденціях (ефект, так би мовити, надмірного порядку апроксимації, або «спроба знайти те, чого немає»), тому, на наш погляд, для стратегічного аналізу, по можливості, слід віддавати перевагу більш простим моделям.

На відміну від наведеного вище огляду, в цій роботі застосовано метод математичного моделювання динамічних процесів з використанням відповідних положень комбінаторного аналізу [1].

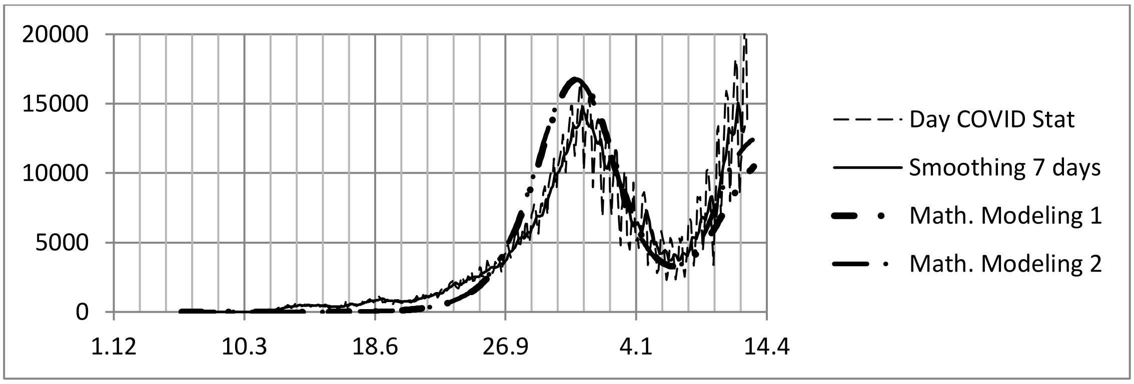

Рисунок. 2 - Офіційна статистика захворюваності на COVID-19 в Україні станом на 30.03.2021 р. та результати її математичного моделювання.

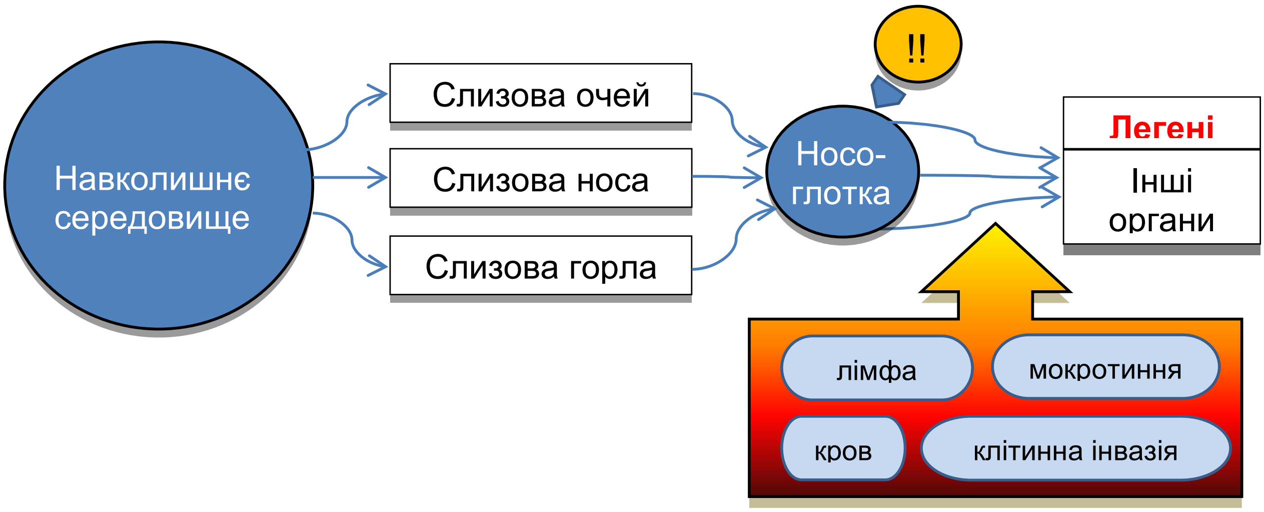

Рисунок. 3 - Передбачувані шляхи розповсюдження COVID-19 організмом людини.

Розглянемо можливі комбінації подій контакту-інфікування людей (орієнтований граф, рисунок 4). Звичайно, можлива ситуація, коли одна інфікована людина заражає велику кількість інших людей за один акт контакту (наприклад, в громадському транспорті), але з урахуванням неодноразового перекриття таких подій, та їх щоденного повторення не буде великою помилкою віднести такі сплески до певного усередненого показника – ймовірності інфікування при контакті P_{inf}. Контакт тут розуміється в широкому смислі як акт разового відкриття шляху передачі інфекції.

Очевидним є той факт, що з усіх можливих комбінацій актів контакту інфікованих та неінфікованих людей, єдиним варіантом інфікування є передача інфекції тільки від хворої (*sick*) до здорової (*helthy*) людини, в той час, коли комбінації *sick-sick, helthy-sick*, *helthy-helthy* ніяк не впливають на факт інфікування. Розгляд випадків масового зараження, або коли здорова людина виконує роль носія інфекції та тому подібних, легко враховуються підбором усередненої величини $P_{inf.}$

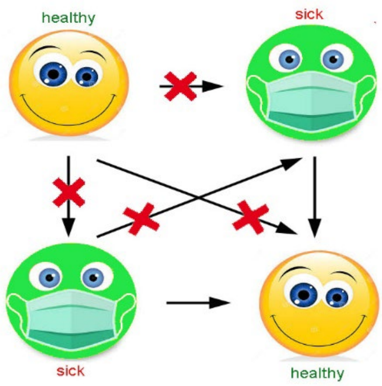

Рисунок. 4 - Варіанти напрямків акту передачі COVID інфекції.

З цього витікає вже не такий очевидний факт: загальну людську популяцію припустимо умовно розділити на дві *незалежні* частини (підгрупи): хворих (sick) та здорових (helthy).

З урахуванням вище викладеного та положень [1], основна розрахункова формула математичної моделі динаміки захворюваності на COVID-19 або подібних інфекцій пропонується як обчислення поєднань в наступному вигляді:

$$\Delta n_{\text{inf}}(t) = N(t)\cdot\left[P(t) - N(t)\right]\cdot P_{\text{inf}}$$
$$N(t+\Delta t) = N(t) + \Delta n_{\text{inf}}(t) \qquad (2)$$

в системі рівнянь (2): $n_{\text{inf}}(t)$ - кількість нових інфікованих за завданий відрізок часу (*t,t+Δt*); N - кількість інфікованих на момент обчислення; $[P(t)-N(t)]$ кількість здорових людей на момент обчислення *t*; $P(t)$ - об'єм людської популяції на момент часу обчислення *t*; $P_{\inf}$ - ймовірність зараження.

Запропонована модель (назвемо її *PN-моделлю*) складається з ОДНОГО диференційного рівняння і є достатньо простою, що спрощує розуміння принципів її функціонування та аналізу.

Додаткові співвідношення пропонованої математичної моделі мають залежний, підпорядкований характер, тому їх фізичний сенс та взаємодія в рамках даного обговорення не наводяться, але вони мають таку ж достатньо чітку мотивацію їх використання, як і рівняння (2).

5.2. Результати досліджень

Етап I (*«Ідеальний» однократний спалах інфекції*). На прикладі ідеалізованого процесу, який за класифікацією [7] можна віднести до примітивної категорії **SI** (*sensitive-infectid*), проведемо аналіз тенденцій розповсюдження ГРВІ (COVID-19). Ознаками «ідеальності» епідемії приймемо наступні:

- кожна людина інфікується одноразово;
- після захворювання людина набуває незнищенного імунітету;
- інфікована людина продовжує розповсюджувати інфекцію достатньо тривалий проміжок часу;
- смертельні наслідки зараження складають обумовлений заздалегідь процент від кількості захворювань.

Останнє припущення не вносить великої похибки моделювання при аналізі достатньо коротких проміжків часу, тим більше, така модель є добрим прикладом для проведення подальшого практичного аналізу.

На рисунку 5 наведено результати одиничного «спалаху» інфекції з використанням моделі *PN-SI.*

Розгляд наведеної інформації, яка була отримана з використанням правдоподібних вихідних даних, дозволяє зробити такі зауваження (зауважимо, для «ідеального» спалаху):

1) захворює, в кінцевому випадку, все населення (рисунок 5а);

2) кількість населення зменшується на величину загиблих (рисунок 5б);

3) денний обсяг заражень має куполоподібну форму, відрізняється стрімким злетом та спадом, що свідчить про наявність в системі позитивного зворотного зв'язку, обмежуваного тільки джерелом заражень по типу феномена горіння, а саме, «спалаху», який закінчується при вичерпанні цього джерела (рисунок 5в);

4) кількість загиблих складає попередньо обумовлений відсоток летальних випадків, обумовлених схильністю людей до такого перебігу захворювання;

5) зменшення ймовірності передачі інфекції не впливає на кінцеву кількість летальних випадків.

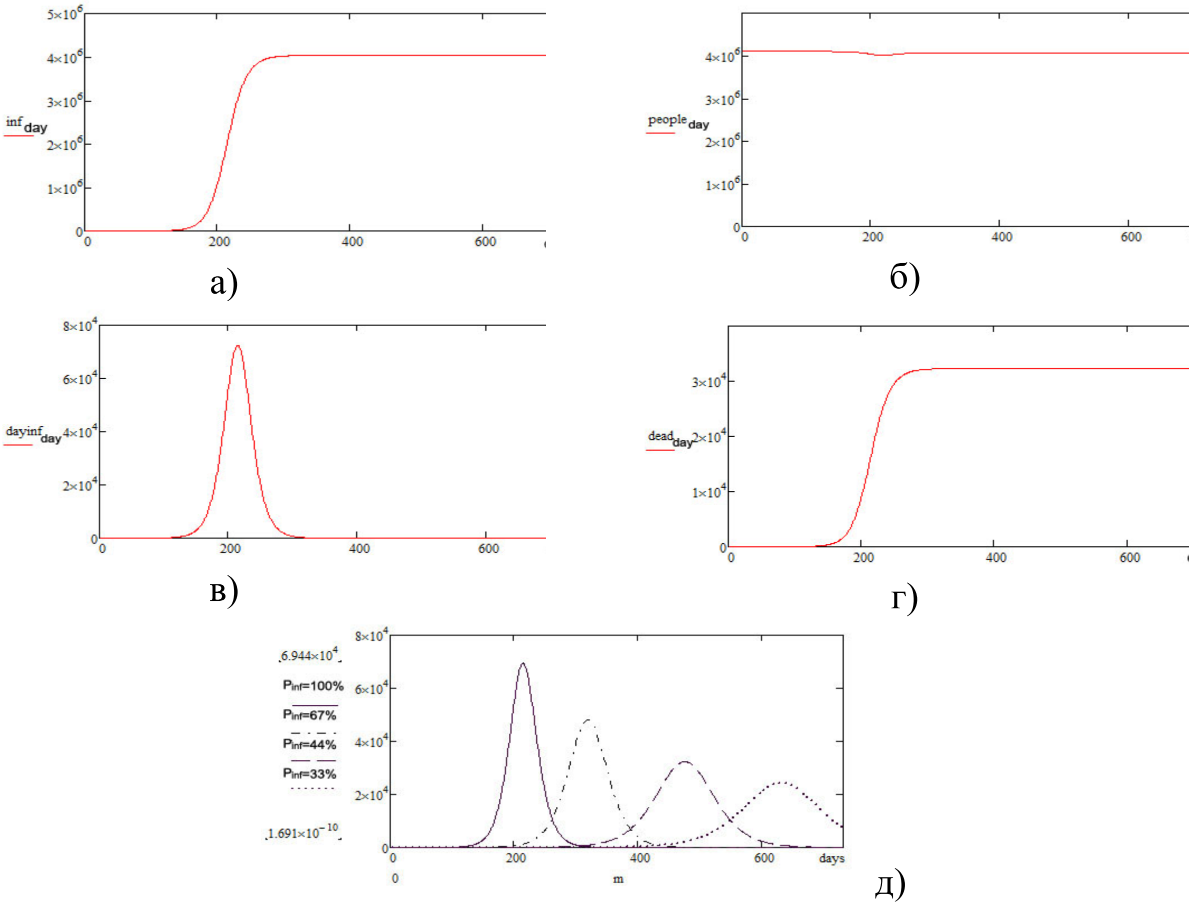

Рисунок. 5. Результати моделювання однократного «спалаху» інфекції із застосуванням *PN-SI* математичної моделі (на графіках *inf* – інфіковані; *people* – обсяг популяції; *dayinf* – денне інфікування; *dead* – померлі).

Тоді, чи взагалі є сенс носіння захисних масок? Чи варте це наших з вами зусиль, зміни звичок та стилю життя, коли підсумкова кількість померлих залишається однаковою, запрограмованою генетичною схильністю? Безперечно, сенс є! Якщо ми подивимось на рисунок 5д, ми зрозуміємо, що разом зі зменшенням величини P_{inf} зменшується також і максимальна величина денного обсягу інфікувань (при цьому відношення дисперсії процесу до його максимального значення залишається постійним в межах похибки). Це дозволяє уникнути колапсу системи охорони здоров'я, як це і казали представники вітчизняного МОЗ.

Тепер, перейдемо до наступного етапу досліджень.

Етап ІІ (*Рециркуляція (відновлення) інфекції*). На прикладі використання удосконаленої моделі, яка за класифікацією [7] може бути віднесена до категорії **SIRS** або **SEIR**, продовжимо теоретичний аналіз тенденцій розповсюдження ГРВІ .

З цією метою, базова модель (2) доповнюється логікою, яка визначає перехід, виключення, або додавання груп осіб з однієї підгрупи до іншої і навпаки.

Основні параметри удосконаленої моделі *PN-SIRS* наведено в таблиці 2.

Таблиця 2. Керуючі параметри моделі *PN-SIRS*

№ з/п	Назва параметру	Позначення.
1	2	3
1.	Ймовірність зараження	$P_{inf.}$
2.	Тривалість активної фази зараження.	T_{inf}
3.	Тривалість імунізації	T_{rec}
4.	Відсоток повторного інфікування, %.	N_r
5.	Відсоток важкого перебігу захворювання від кількості інфікованих	N_h
6.	Відсоток летальних випадків від кількості інфікованих.	N_d
7.	Початковий об'єм популяції населення.	N_0

Вибір поведінкової моделі інфекції виду **SIRS** обумовлений наявністю відкритих даних щодо неодноразового повторного інфікування людей, які вже

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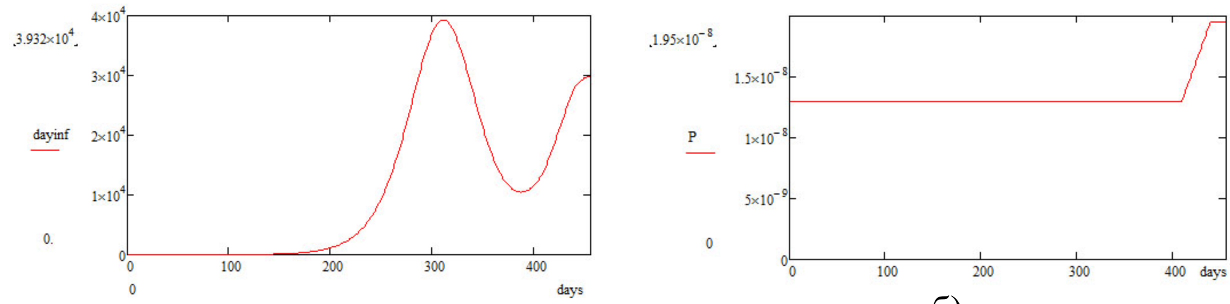
перехворіли на COVID-19, тобто наявний ефект поступового зникнення імунітету до нього (рециркуляція інфекції, або схильність коронавіруса до суттєвих мутацій та відновлення хвороботворності). Справедливості раді треба відзначити, що любий сценарій перебігу епідемії легко вкладається в пропоновану в роботи модель шляхом додання відповідної логіки яка визначає перехід, виключення, або додавання осіб з однієї підгрупи *P* до *N* і навпаки.

Нижче, на рисунку 6 наведено результати моделювання захворюваності на з використанням моделі. *PN-SIRS.*

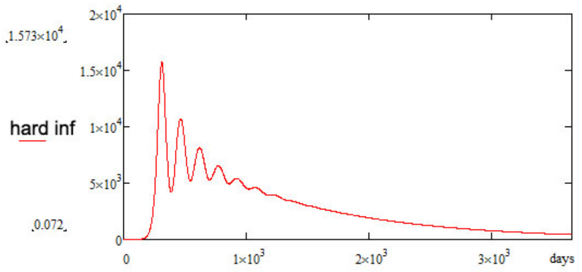
Однією з особливостей розробленої моделі є те, що інтенсивність заражень вірусом певної мутації за рахунок рециркуляції інфекції має поступово знижуватися (Рисунок 6а та лінія math modeling 1, рисунок 1) та це, мабуть, якась фундаментальна властивість розробленої моделі.



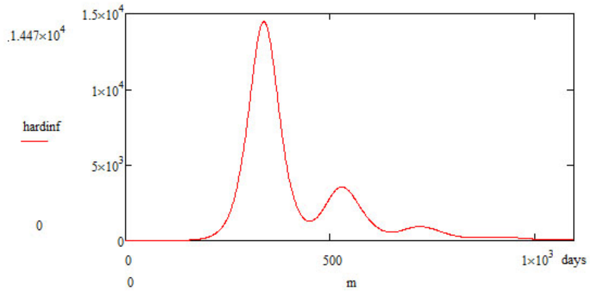
а) б)

Рисунок. 6. Результати моделювання перебігу інфекції із застосуванням *PN-SIRS* математичної моделі (на графіках *P* – ймовірність інфікування; *hardinf* – кількість хворих середньої або великої важкості денного інфікування).

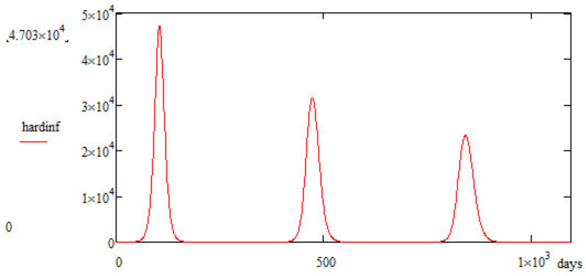
Тому це прийшлося врахувати введенням з початку 2021 року «англійської мутації» коронавіруса (Рисунок 6б та лінія math modeling 2, рисунок 2), на 50% заразнішої, ніж попередня для кращого збігу зі згладженою статистикою захворюваності (лінія Smoothing 7 days, рисунок 2).



а)



б)



в)

Рисунок. 7. Результати моделювання перебігу інфекції із застосуванням *PN-SIRS* математичної моделі (на графіках *P* – ймовірність інфікування; *hardinf* – кількість хворих середньої або великої важкості денного інфікування).

Подальша перспектива характеру динаміки захворювань може полягати в настанні динамічної рівноваги інтенсивності захворювань та одужань (Рисунок 7а), швидкого затухання пандемії (Рисунок 7б), або продовження циклічних епідемій (Рисунок 7в) в залежності від співвідношень параметрів моделі (таблиця 2).

Розглянемо тепер взяті з відкритих повідомлень в пресі найбільш ймовірні шляхи виникнення важких легеневих ускладнень COVID-19, а саме, важка інфекційна дихальна недостатність. Як видно з рисунку 3, єдине місце, в якому практично можливо знешкодити вірус, є носоглотка в період попереднього розмноження (інкубації) вірусу, де його можна спробувати дезінфікувати.

Однак становище ускладнюється тим, що носоглотка – це теж слизова оболонка і вибір дезінфікуючих засобів вкрай обмежений, враховуючи необхідність уникнення пошкодження (опіку, некрозу) її та прилеглих тканин. Тому вважаємо, що є сенс спробувати сприйнятливий та нешкідливий засіб пригноблення вірусу, запропонований [15,16] в YouTube каналі «Зменшимо сприйнятливість до COVID та грипу».

5.3. Практична значимість.

В роботі розроблені математичні моделі розвитку захворюваності на COVID-19 або інші подібні захворювання, які з урахуванням зменшення параметрів, що визначають властивості та поведінку об'єкту дослідження, більш керовані в плані оцінки заходів з полегшення перебігу захворювань. Мінімальна розмірність системи диференційних рівнянь, яка описує перебіг епідемії, дозволяє більш змістовно оцінювати їх вплив на динаміку захворюваності. Вказана модель може відтворювати різні сценарії розвитку захворювання. Практична значимість дослідження полягає в тому, що дослідження дозволяють перевіряти ефективність різні методи обмеження захворювань на ГРВІ (COVID-19, або подібних) досліджувати перспективи розповсюдження захворювання.

Висновки

Запропоновано математичну модель динаміки захворювань на COVID-19 та інших подібних інфекцій. Проведені дослідження свідчать:

а) запропонована PN-модель придатна для відпрацювання методів стримування розповсюдження інфекції COVID-19;

b) знешкодження COVID-19 є найбільш перспективним на етапі інкубації в області носоглотки шляхом застосування м'яких дезінфекторів.

На даний момент проводяться дослідження впливу на динаміку та перспективи розповсюдження COVID-19 та інших ГРВЗ загальновживаних заходів з його стримування (самоізоляція, карантин громадського транспорту, імунізація та інше.)

KAPITEL 6 / *CHAPTER 6* [6]
THE ROLE OF LEPTIN AND C-REACTIVE PROTEIN BIOMARKERS IN PATIENTS WITH STABLE ANGINA: THE RELATIONSHIP WITH CLINICAL MANIFESTATIONS AND PROGNOSIS

DOI: 10.30890/2709-2313.2024-32-00-014

The metabolic role of leptin in the emergence and progression of cardiovascular pathology

Adipose tissue is an active endocrine and paracrine organ and exhibits a high level of metabolic activity, synthesis and secretion of biologically active mediators (adipocytokines) associated with energy metabolism. Among them, adiponectin, resistin, visfatin, retinol-bound protein-4 and leptin are distinguished, which, in addition to regulating body weight, influence inflammation, insulin resistance and diabetes, regulate metabolism and the immune response, and also have a direct effect on epitheliocytes , the structure and functions of the heart and the cardiovascular system as a whole [7].

In addition to subcutaneous adipose tissue, epicardial adipose tissue is an important part of visceral fat and has a high metabolic rate [10], and it also locally interacts with coronary arteries and may locally potentiate the development of coronary heart disease (CHD). Local and systemic concentrations of adipocytokines are correlated with the presence of coronary artery disease, and may be promising markers for monitoring cardiovascular risk in patients. In patients with CAD, the level of pro-inflammatory cytokines, such as interleukin-1β, -6, as well as leptin, neurohumoral factors and their receptors is significantly higher in epicardial adipose tissue, regardless of the plasma level of these molecules [7, 12].

Leptin primarily regulates food intake and energy homeostasis through a unique mechanism. Activation of leptin receptors leads to inhibition of orexigenic pathways with the participation of neuropeptide Y and simultaneous activation of anorexigenic pathways. The effect of this biomarker is implemented at the level of the hypothalamus, where it binds to receptors, suppressing the urge to eat and increasing energy

[6]**Authors:** *Tashchuk Viktor, Amelina Tetiana, Hinhuliak Oleksandr*

expenditure. A high level of this mediator is also associated with the occurrence of metabolic syndrome [10].

Leptin activates immune cells and stimulates the cellular immune response, affects the production of pro-inflammatory cytokines or by direct action on the vascular wall and is a mediator of proatherogenic mechanisms with the possibility of influencing the onset and progression of atherosclerosis, stimulates the activity of the sympathetic nervous system, and induces the activity of atherosclerotic plaque [11]. Clinical studies indicate a correlation of leptin levels with cardiovascular risk factors such as lipid concentrations and blood pressure (BP) levels, as well as with endothelial dysfunction and inflammation.

Obesity is caused by an imbalance between calorie intake and energy expenditure, which causes excessive accumulation of triglycerides in adipose tissue in various parts of the body. An increase in visceral adipose tissue is associated with diabetes, while pericardial adipose tissue is associated with cardiac pathology. Adipose tissue can increase either through cellular hypertrophy or hyperplasia, with the former correlating with decreased metabolic health in obesity [5].

Leptin resistance or a deficiency in leptin signaling leads to an increased risk of cardiac dysfunction and heart failure, which is a major cause of morbidity and mortality associated with obesity and T2DM [9].

However, some studies did not demonstrate a statistically significant association between leptin levels and the risk of coronary heart disease, the relationship between leptin and the progression of coronary heart disease was considered to be moderate and more dependent on body mass index [11].

According to other researchers, adiponectin and leptin play an important pathogenetic role not only in the occurrence, but also in the severity and scale of the complexity of coronary artery damage in patients with CAD. Independent predictors of the severity of atherosclerosis are a low level of adiponectin and a high level of leptin, as well as a high level of LDL cholesterol [3].

The role of C-reactive protein in the progression of cardiovascular diseases, the relationship with leptin

It has been established that leptin induces the production of C-reactive protein (CRP), and its level is positively correlated with the level of such markers of atherosclerotic plaque activation as CRP and troponin I [1].

CRP is the most widely studied reactant of the acute phase and a sensitive marker of inflammation associated with several stages of atherogenesis, from the beginning to the appearance of clinical manifestations. Inflammation in atherosclerotic plaque can cause unstable angina by promoting rupture and erosion. The size of the atherosclerotic plaque and its destabilization due to inflammatory processes are the main determinants of ischemia and acute coronary syndrome (ACS).

Elevated CRP after acute myocardial infarction (MI) is associated with adverse outcomes, including cardiac rupture, left ventricular (LV) aneurysm development, and cardiac death, with alterations in LV structure and function. Elevation of CRP exacerbates LV dysfunction and contributes to adverse post-infarction LV remodeling, which may be associated with increased apoptosis, macrophage infiltration, and metalloproteinase-9 activity in surrounding myocardial zones. Elevated levels of CRP have been associated with unstable angina pectoris, acting as a risk factor for serious adverse cardiac events [6].

Oxidized low-density lipoprotein (LDL) and CRP are positively correlated in patients with ACS, confirming their direct role in the progression of the inflammatory component in the pathogenesis of atherosclerosis. An increase in the concentration of CRP in the early period of ACS, before tissue necrosis, can be a surrogate marker of concomitant CVD. STEMI patients had significantly higher CRP levels compared to NSTEMI patients. Assessment of CRP content can help in risk stratification after MI [2].

The level of CRP is an independent predictor of rapid angiographic progression of coronary artery (CA) stenosis and is significantly correlated with the angiographic degree of CA stenosis. CRP can also serve as a useful biomarker for improving risk assessment and secondary prevention of CAD in patients without hypercholesterolemia

[8].

Elevated plasma levels of both leptin and CRP have been reported in a number of conditions, including obesity, and have been associated with cardiovascular pathophysiology and increased cardiovascular risk. Interestingly, these two biomarkers are able to mutually regulate their bioavailability through complex mechanisms that are not yet fully understood. There is clinical evidence to suggest not only an independent correlation between circulating levels of CRP and leptin, but also that their assessment in tandem may lead to an increased ability to predict CVD. Clinical data highlight the importance of both markers for cardiovascular risk assessment and strongly suggest that additional value will be gained by assessing them together, especially in clinical conditions such as obesity where chronically elevated CRP levels and leptin resistance coexist. Molecular studies show that leptin is able to modulate CRP expression levels, both indirectly through its action on other pro-inflammatory molecules such as IL-6, and directly by promoting its production in the liver and blood vessels. In turn, CRP can regulate the bioavailability of leptin in the blood circulation, since it has been demonstrated that in extracellular conditions the two molecules co-precipitate, this interaction impairs the ability of leptin to bind its receptor and activate intracellular signaling [4].

The exact relationship between hyperleptinemia and CVD remains incompletely defined. It is still unknown whether hyperleptinemia itself or the presence of leptin resistance in obese individuals contributes to CVD. The conflicting findings in these cases suggest that additional factors such as age, sex, BMI, and dietary habits should be taken into account when evaluating the effects of leptin on cardiovascular health [12].

Research material and methods

In order to evaluate the dependence of leptin levels and the state of coronary and functional reserves in patients with stable angina pectoris (AP), 42 patients with a diagnosis of AP II and III functional classes (FC) were examined. All patients were divided into three clinical groups - 1st - patients with an increase in the initial level of leptin (50.0% of cases), 2nd - patients with no changes in leptin level (11.90% of cases) and 3rd – patients with a decrease in the initial level of leptin (38.10% of cases). At the beginning of inpatient treatment and after 3 months. all patients underwent clinical, laboratory and instrumental examination.

The research used general clinical objective methods of examination with measurement of blood pressure, resting heart rate (HR) and determination of anthropometric indicators, laboratory (study of lipid profile, determination of blood leptin and CRP) and non-invasive instrumental (electrocardiography (ECG), echocardiography (echocardiography), cycle ergometry (CEM)) examination. Transthoracic echocardiography was performed according to the usual protocol in M- and B-modes on a Toshiba "SAL-38AS" device (Japan) to assess the structural and functional state of the heart chambers, LV systolic function. End-systolic (HR) (cm) and end-diastolic (KDR) LV (cm), thickness of the interventricular membrane in diastole (TMShPd) (cm) and thickness posterior wall (TSS) LVd (cm) was determined from the left parasternal approach along the long axis in the B-mode according to the Penn convention method. Blood leptin and CRP levels were measured by ELISA using the DRG reagent kit (Germany) for leptin and for HS- CRP. According to this method, the reference levels of leptin were considered to be 2.05-5.63 ng/ml for women. 3.63-11.09 ng/ml. The reference levels of CRP are 0.068-8.2 mg/l. Statistical processing of the obtained electronic databases was carried out using the programs "Microsoft Excel 97" and "Statistica for Windows v 5.0" (StatSoft Inc., USA) with calculation of average values and their standard errors and determination of probable quantitative difference indicators using the Student's t-test with a significance level at p for the t-test <0.05.

Research results

In an intergroup comparison, it was noted that more severe angina pectoris and heart rhythm disturbances are associated with a subsequent increase in the level of blood leptin, likely when comparing patients with growth and an unchanged level of this marker ($p<0.05$ and $p<0.001$, respectively) and unlikely when comparing the group with increase and decrease of blood leptin (in both cases $p>0.1$). Heart failure (HF) of the II A century. predicts further growth of the analyzed indicator is improbable when comparing all groups (in both cases $p>0.1$). According to the literature, an increase in

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the level of leptin is closely related to an increase in the risk of developing HF in men, regardless of body mass index [12]. The dynamics of the level of the studied indicator does not depend on the age and gender of the patients, as well as the presence of hypertension (in all cases p>0.5) (Table 1).

Table 1 - Clinical characteristics of patients of groups with different blood leptin dynamics

Indicator	The level of leptin increased	Leptin levels did not change	Leptin level decreased
Age, years	49.62±1.26	46.60±3.14	49.24±1.45
Women, %	52.38±10.90	20.00±12.89	50.00±12.50
Men, %	47.62±10.90	80.00±12.89	50.00±12.50
AP III FC, % of cases	71.43±9.86	20.00±12.89*	50.00±12.50
AP II FC, % of cases	28.57±9.86	80.00±12.89*	50.00±12.50
AG, % of cases	85.71±7.64	60.00±21.91	81.25±9.76
HF IIA, % of cases	52.38±10.90	20.00±12.89	31.25±11.59
Rhythm disturbances, % of cases	38.10±10.60	0*	18.75±9.76

*Note. *- probable differences between groups with growth and unchanged leptin level (p<0.05).*

The following is noted when analyzing the parameters of laboratory research. Along with a probable decrease in the level of leptin (p<0.001), an improbable decrease in the content of triglycerides (TG) (p>0.1), LDL cholesterol (cs) (p>0.1) with a tendency to decrease in total cholesterol was determined. The levels of CRP and HDL cholesterol in this group did not change (in both cases p>0.5). With a probable increase in leptin (p<0.001), a tendency towards an increase in CRP (p>0.2) and total cholesterol (p>0.2) was noted with an unchanged concentration of LDL cholesterol (p>0.5), HDL cholesterol (p>0 .5) and TG (p>0.5). At the same time, positive dynamics are associated with a likely more frequent decrease in CRP (respectively, 62.5±12.1 and 28.57±9.86% of cases, p<0.05), total cholesterol (respectively, 50.00±12.5 and 9 ,52±3.4% of cases, p<0.05), improbably more frequent decrease in TG (respectively 50.00±14.43 and 22.22±9.80% of cases, p>0.1) and with the absence of a single case of LDL-C growth.

In patients with an unchanged level of leptin (p>0.5), there were no significant changes in CRP (p>0.5) and total cholesterol (p>0.5), however, a tendency to decrease LDL cholesterol (p>0 ,2), TG (p>0.2) and HDL cholesterol growth (p>0.2). When comparing the 1st and 2nd groups, only with unfavorable changes in the level of leptin, there was an increase in total cholesterol and LDL cholesterol, a decrease in TG was determined incredibly less often (respectively, 22.22±9.80 and 50.00±25.00, p>0 ,1), the growth of HDL cholesterol is probably less frequent (respectively 33.33±15.71 and 100% of cases, p<0.001) (Table 2).

Table 2 - Laboratory characteristics of patients of groups with different blood leptin dynamics

Indicator	Leptin level increased		Leptin levels did not change		Leptin level decreased	
	Start of observation	End of observation	Start of observation	End of observation	Start of observation	End of observation
Leptin, ng/ml	9.65±1.38	23.2±4.06	11.74±4.29	11.04±3.98	26.18±4.17	9.53±2.41
CRP, mg/l	4.50±1.05	6.44±1.70	2.00±1.12	4.14±2.58	3.82±0.97	4.87±2.04
Total cholesterol, mmol/l	5.11±0.27	5.52±0.32	5.45±0.60	5.02±0.53	4.77±0.23	4.55±0.28
HDL cholesterol, mmol/l	1.72±0.16	1.6±0.22	1.62±0.26	1.9±0.22	2.22±0.17	2.14±0.24
LDL cholesterol, mmol/l	4.41±0.33	4.60±0.46	4.99±1.43	3.00±1.46	4.84±0.36	4.18±0.4
TG, mmol/l	2.27±0.19	2.39±0.13	2.45±0.46	2.08±0.25	1.98±0.14	1.72±0.17

*Note. *- probable differences within the group (p<0.05).*

Examination of the echocardiogram parameters (Table 3) showed the absence of a relationship between any dynamics of the leptin level and changes in LV volumes and ejection fraction (EF) of the LV, since these indicators did not change significantly in all groups (in all cases p>0.5). This is consistent with some literature data that the level of this marker does not significantly correlate with indicators of LV diastolic and systolic function in men and women [10].

When analyzing the data of the bicycle test, it was established that a decrease in the blood leptin level is correlated with a probable increase in the parameters of the threshold load (PN) (p<0.01) and the work performed (p<0.05), while with an increase in leptin, the increase in these indicators is improbable (respectively p>0.1 and p>0.2). No significant differences in the frequency of detection of the specified changes were found in any of the groups - in relation to PN, respectively, 53.85 ± 13.83 and 50.00 ± 11.79% of cases (p>0.5) and in relation to the performed work, respectively, 46.15 ± 13.83 and 50.00±11.79% of cases (p>0.5).

Table 3 - Characterization of the results of instrumental studies of patients of groups with different blood leptin dynamics

Indicator	The level of leptin increased		Leptin levels did not change		Leptin level decreased	
	Start of observation	End of observation	Start of observation	End of observation	Start of observation	End of observation
EDV LSH, Jr	113.92±6.12	108.81±3.81	103.84±11.94	103.84±11.94	116.14±8.09	116.14±8.09
ESV LSH, Jr	46.38±3.82	43.19±2.26	37.68±6.04	37.68±6.04	45.78±3.39	45.78±3.39
LVEF, %	59.62±0.97	60.14±0.80	63.40±2.69	63.40±2.69	59.88±0.78	60.06±0.76
Mon, Tues	68.84±8.31	84.75±9.83	125.40±17.73	153.40±19.79	84.54±7.81	124.39±13.10*
Work, kJ	20.36±3.86	25.54±4.20	49.98±10.02	59.68±12.08	24.30±3.47	42.54±6.31*

*Note. *- probable differences within the group (p<0.05).*

Patients with an unchanged level of leptin have an improbable increase in PN (p>0.1), however, the performance indicator did not change (p>0.5). When comparing the 1st and 2nd groups, the frequency of detection of an increase in the specified parameters does not differ - in both cases, respectively, 50.00 ± 11.79% and 60.00 ± 21.91 cases ($p>0.5$).

Correlation analysis revealed a weak probable inverse correlation between blood leptin level and PN ($r=-0.3$, $p<0.05$) (Figure 1).

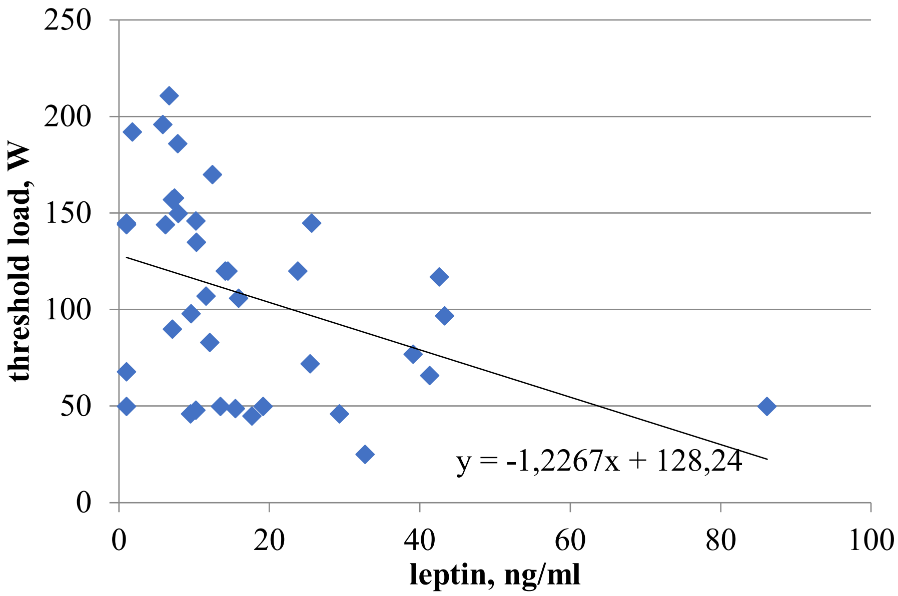

Figure 1 - Correlation between blood leptin level and threshold load.

Thus, leptin is a predictor of higher FC of angina pectoris and heart rhythm disorders, and a decrease in its level is accompanied by an increase in PN indicators and work performed during a stress test with a weak probable inverse correlation between the level of blood leptin and PN. Hyperleptinemia predicts negative changes in the lipid composition of the blood, as it is accompanied by an increase in total cholesterol, LDL cholesterol, as well as a less frequent increase in HDL cholesterol. Leptin can be used as an indirect marker of systemic inflammation, since a decrease in its level predicts a more frequent decrease in CRP. Further study of the role of leptin in the progression of atherosclerosis is expedient in order to determine risk stratification in AP.

Conclusions

1. The female gender predicts a higher blood leptin level ($p<0.01$) with the preservation of this tendency in the distribution according to the severity of angina pectoris. A decrease in the initial level of leptin is accompanied by an increase in threshold load indicators ($p<0.01$) and work performed during a stress test ($p<0.05$) with a weak probable inverse correlation between blood leptin level and threshold load ($r=-0.3$, $p<0.05$).

2. Leptin can be used as an indirect marker of systemic inflammation, since a decrease in its level predicts a more frequent decrease in C-reactive protein ($p<0.05$).

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KAPITEL 7 / *CHAPTER 7* [7]
THE POTENTIAL OF TRIMETHYLGLYCINE AS A MEANS OF THE COMPLEX REGULATION OF CARBOHYDRATE METABOLISM IN HYPERGLYCEMIA AND OBESITY

DOI: 10.30890/2709-2313.2024-32-00-006

Introduction

Since 2021, we have been researching means of regulating metabolic processes with the help of bio-protectors—substances of different chemical natures that can stabilize the body's biochemical processes under the influence of aggressive exogenous factors.

Trimethylglycine showed the most promising results among several substances. Trimethylglycine is a donor of methyl groups -CH_3, which determines its ability to neutralize chemically active radicals. Our experiment on animal models demonstrated a pronounced antioxidant effect of trimethylglycine in alcohol-induced oxidative stress [1]. Brief results of this experiment showing the hepatoprotective effect of trimethylglycine are presented below (Table 1).

Table 1 - Activity of transferases (AST, ALT and GGT) in the blood of rats, U/L (in control group, 2 group (EtOH) and 5 group (EtOH + trimethylglycine) of animals; *M*±*m*, *n*=7)

Groups of animals → / Enzymatic activity ↓	Control	2	5
AST, U/L	98.1±4.9	197.6±10.9**	110.1±7.1##
ALT, U/L	79.2±4.7	169.3±8.8**	91.3±6.9##
GGT, U/L	6.9±0.7	19.7±1.1**	9.2±0.6*##

*Note: data are statistically significant (*p<0.05 and **p<0.001) compared with the control group and # p<0.05, and ##p<0.001 compared with the 2nd experimental group, respectively*

At first, we thought that trimethylglycine's hepatoprotective effect was due to its antioxidant properties, which are explained by its chemical structure (Table 2).

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However, further study of its properties demonstrated its anti-inflammatory properties, which are discussed below.

Table 2 - Activity of oxidoreductases (LDH, SOD and catalase) and the content of malonic dialdehyde (MDA) in the blood serum and liver tissue of rats (in control group, 2 group (EtOH) and 5 group (EtOH + trimethylglycine) of animals; *M*±*m*, *n*=7)

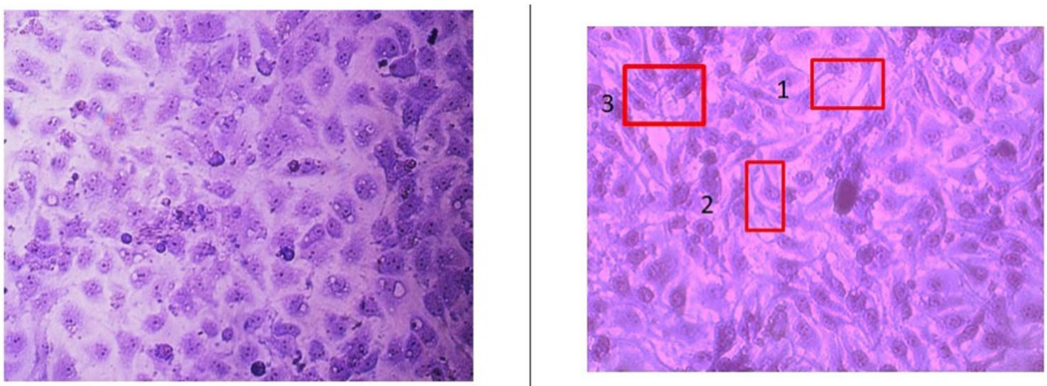
Groups of animals → / **Biochemical parameters ↓**	**Control**	**2**	**5**
LDH, U/L	489±18.2	990±28.3**	610±19.1**##
SOD, U/mg of protein/min	260±21.2	148.5±15.3**	220.2±14.2#
Catalase, U/mg of protein/min	239.8±11.3	139.3±9.1**	179.7±12.1*#
MDA, nmol/mg of protein	40.9±2.3	56.3±4.1*	42.1±1.8#

*Note: data are statistically significant (*p<0.05 and **p<0.001) compared with the control group and # p<0.05, and ##p<0.001 compared with the 2nd experimental group, respectively*

The COVID-19 epidemic has also awakened our interest in the role of inflammation in the dysfunction of endothelial cells, which are the target cells for the SARS-CoV-19 virus. For this reason, we focused on the anti-inflammatory effects of trimethylglycine, particularly its ability to inhibit the NF-κB signaling pathway, which is responsible for the secretion of IL-1β, and its ability to regulate TLR4.

Our second discovery was the effect of trimethylglycine on the culture of porcine aortic endothelial cells. The addition of trimethylglycine to the culture solution promoted cell division, which increased the volume of cell mass by 20% compared to the control group [2].

Also, under the influence of trimethylglycine, endothelial cells began to form more complex morphological structures, presumably precapillary (Figure 1).



Culture medium | Culture medium + trimethylglycine

Figure 1 - Confirmation of signs of cell differentiation (cell elongation (2) and formation of precapillary structures (1,3)) of the endothelium under the action of trimethylglycine.

Thus, we have a biologically active substance (trimethylglycine) that:

✓ has antioxidant properties by neutralizing free radicals;

✓ has anti-inflammatory properties by regulating the NF-κB signaling pathway;

✓ has a beneficial effect on endothelial cells, promoting their proliferation and complicating their morphological structure.

Also, the main mechanisms of the development of non-alcoholic fatty liver disease:

- energy stress of the cell caused by excess calories (excess free radicals);
- violation of the intestinal barrier (dysfunction of endothelial cells);
- inflammatory process as a result of the two previous factors.

Thus, this article will consider how trimethylglycine can correct metabolic processes in non-alcoholic fatty liver disease and type 2 diabetes mellitus.

7.1. Potential of trimethylglycine for mitochondria, oxidative stress and development of non-alcoholic fatty liver disease

It is necessary to clarify that non-alcoholic liver disease is a complex of structural and functional changes in the liver that develop in stages:

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1. Steatosis - accumulation of lipids in hepatocytes without their structural and functional changes.

2. Non-alcoholic steatohepatitis - occurrence of inflammation as a result of functional changes.

3. Fibrosis and cirrhosis - occurrence of irreversible structural changes.

Since direct metabolic disturbances occur in the early stages, we will consider these clinical conditions i

Steatosis is an adaptive response of hepatocytes to caloric stress and is an excessive accumulation of intracellular triglyceride stores. Lipid accumulation in hepatocytes should be considered as a balance between the metabolic processes of adipose tissue lipolysis, an increase in free lipids in the blood and their absorption, *de novo* lipogenesis on the one hand, and fatty acid oxidation and the secretion of very low-density lipoproteins on the other hand (Figure 2).

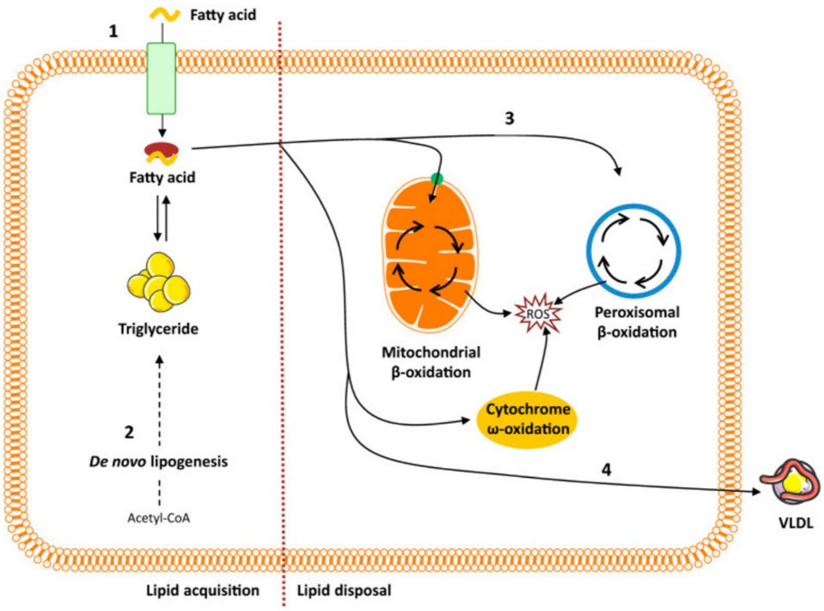

Figure 2 - Simplified diagram of lipid metabolism in the liver [3]. Although the absorption of free fatty acids (1) and their extraction from hepatocytes by secretion of very low-density lipoproteins (4) affect the number of intracellular lipids, the development of oxidative stress is associated with the processes of lipogenesis *de novo* (2) and lipid oxidation (3).

The primary protective reaction to an increase in the level of intracellular lipids is an increase in the intensity of β-oxidation of fatty acids, with subsequent induction of tricarboxylic acid cycle and stimulation of oxidative phosphorylation—at least due to the substrate acetyl-CoA, which is formed as a result of β-oxidation of fatty acids. Although the process occurs primarily in the mitochondria, lipid overload, and impaired mitochondrial function cause higher levels of fatty acid oxidation in peroxisomes and cytochromes, generating reactive oxygen species (ROS) [3-4].

It should also be noted that chronic free fatty acids overload of hepatocytes leads to a decrease in their transport rate into the mitochondria. This, in turn, reduces the activity of the mitochondrial respiratory chain, which reduces ATP synthesis. Decreased ATP levels may be responsible for the induction of endoplasmic reticulum stress and activation of the unfolded protein response, which stimulates *de novo* lipogenesis pathways and further aggravates liver steatosis [5].

In parallel, there is an accumulation of mitochondrial cholesterol, which leads to changes in the inner mitochondrial membrane and depletion of mitochondrial glutathione (GSH) [6].

In fact, trimethylglycine can utilize ROS by donating a methyl group -CH_3 and participating in the methionine cycle [1,7] (Figure 3).

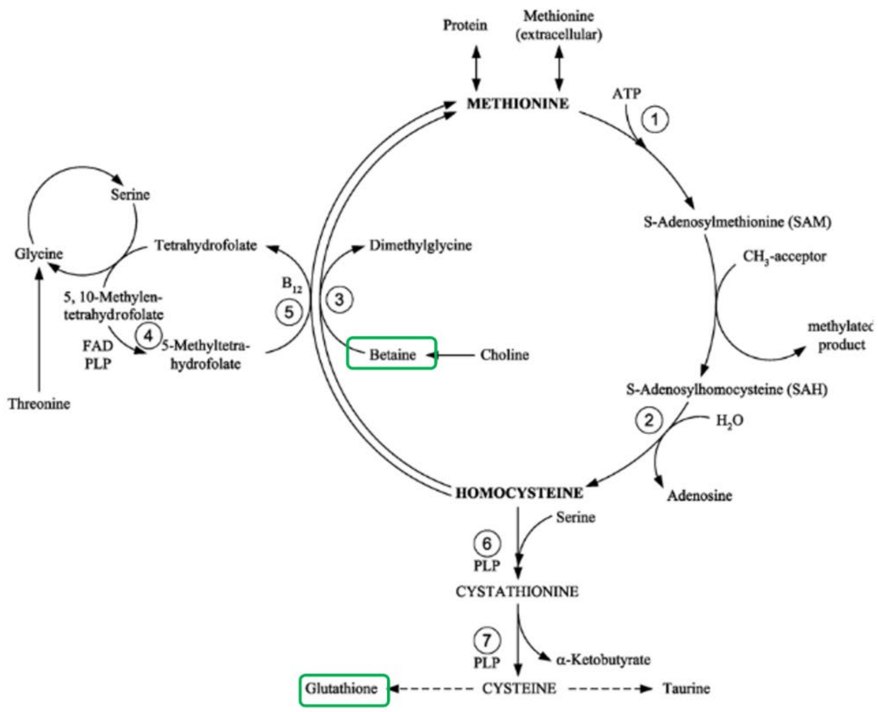

Figure 3 - Methionine cycle and intermediates (adapted [8])

7.2. Potential of trimethylglycine in intestinal barrier dysfunction, inflammation and non-alcoholic fatty liver disease

As mentioned above, the protective mechanism consists of the adaptation of adipose tissue to excessive fat intake. The first stage of this adaptation is an increase in the number of adipocytes (hypertrophy). This is followed by proliferative processes leading to an increase in the number of adipocytes (hyperplasia). At this stage, the adaptation process takes place without violating the structural and functional integrity of the organism, but up to a certain limit. In the second stage, a critical adaptation of the adipocytes to the excessive accumulation of triglycerides occurs by activating inflammatory signaling pathways. The most important of these is the NF-κB kinase inhibitor/nuclear factor κB pathway, in which free fatty acids activate receptors of the toll-like receptor TLR-4, which is located on the surface of macrophages and adipocytes. This results in the release of interleukins IL-1 and tumor necrosis factor TNF-α. At the same time, insulin is inhibited in the presence of TNF-α tumor necrosis factor [8].

One of the strategies for treating insulin resistance is to use drugs that block the synthesis of TNF-α. For example, berberine is a natural isocholone alkaloid that inhibits MEKK1 and MEK1/2 [9], through which TNF-α affects the DNA of cells and consequently their insulin resistance (Figure 4).

It should be noted that the canonical mechanism of anti-inflammatory action of trimethylglycine is the suppression of NF-κB activity and IL-1β expression by inhibiting MAPK and NIK/IKK - it suppresses the expression of HMGB1 mRNA and protein, which regulates the activation of TLR4, which is involved in the activation of NF-κB, as well as HDAC3, which binds to IκBα to activate NF-κB [10]. This suggests that the therapeutic potential of trimethylglycine may be similar to that of berberine.

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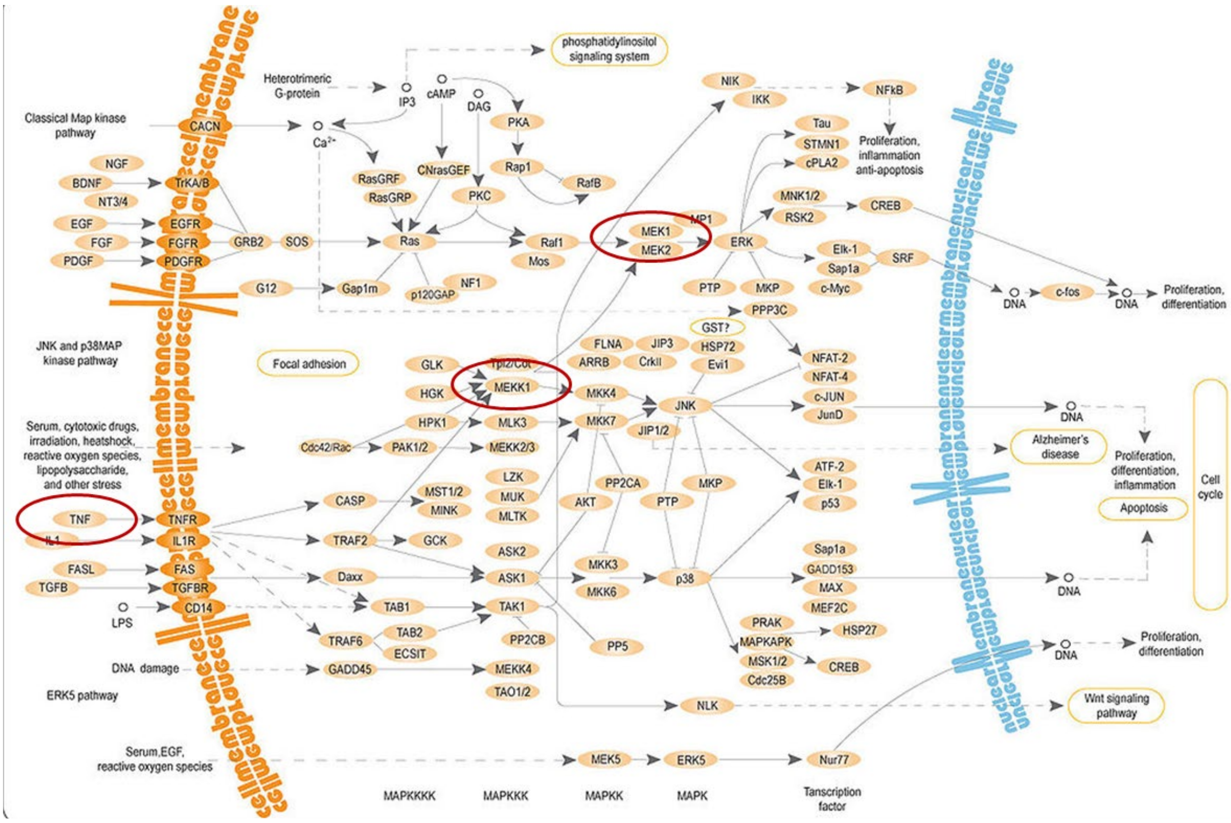

Figure 4 - MAPK pathway and berberine therapeutic targets (circled red)

At the same time, the role of the intestinal barrier in the development of an inflammatory response and the subsequent cascade of biochemical changes in the metabolism must be taken into account. Obesity is often associated with an active growth of bacteria in the small intestine. As a result, the permeability of the intestinal barrier is disrupted and bacterial products, lipopolysaccharides (LPS), enter the liver from the intestine via the biliary system or the portal vein. Products and metabolites of the intestinal microbiota reach Kupffer cells and cause inflammation via LPS/Toll-like receptor TLR4, releasing cytokines, including TNF-α [11] (Figure 5).

Considering the ability of trimethylglycine to inhibit the receptor TLR4, as well as its effect on the morphology of endothelial cell cultures, we believe that trimethylglycine can reduce the manifestation of the inflammatory process when the intestinal barrier is disrupted.

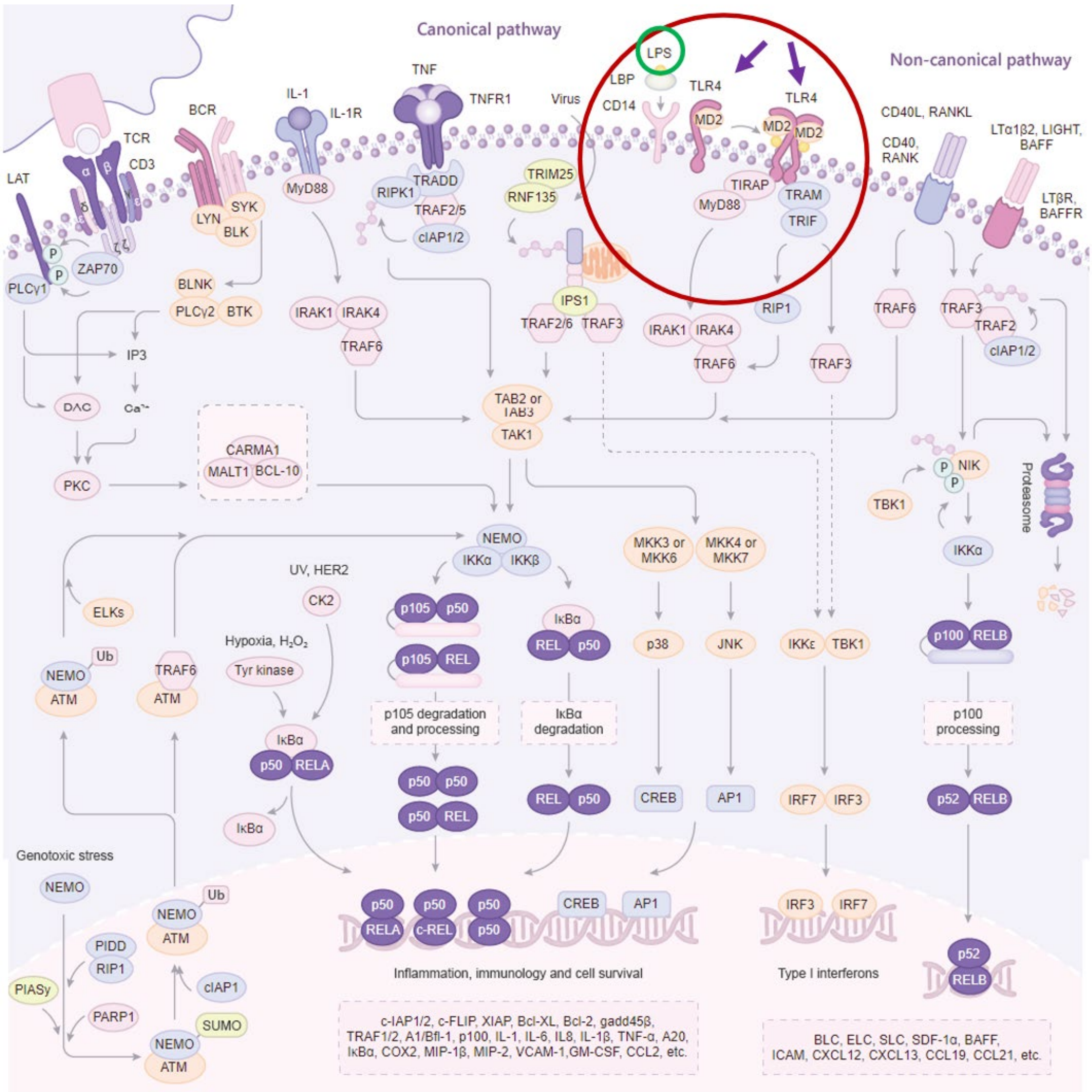

Figure 5 - LPS/Toll-like receptor TLR4 mediated inflammation by gut microbiota products and metabolites (adapted [12])

Summary and conclusions

Type 2 diabetes mellitus should be viewed as a persistent morphofunctional change caused by a complex of cascading biochemical abnormalities. Considering that the causes of these biochemical derangements persist even when the clinical picture of type 2 diabetes mellitus occurs, we believe that by influencing these causes we will be able to stabilise the metabolism. In particular, by analogy with berberine, we believe that trimethylglycine will be able to influence hyperglycaemia based on its ability to influence key factors in the development of hyperglycaemia (cellular stress, intestinal barrier disruption, inflammatory reactions and insulin inhibition).

KAPITEL 8 / *CHAPTER 8* [8]
THE IMPORTANCE OF AUTOMATION AND ELECTRIFICATION FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT

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Introduction

Efficient use of water and energy resources in agriculture today is impossible without automation and electrification of basic processes. The introduction of modern technologies for managing water and energy resources based on automated systems and alternative energy sources makes it possible to significantly optimize the work of farms. This is especially important in the context of global climate change and scarcity of natural resources, which requires new approaches to maintain sustainable agricultural production. Agriculture traditionally consumes significant amounts of water and energy, especially for irrigation, tillage and transportation of products. However, in the context of increasing resource scarcity and climate change, the task of transition to sustainable agriculture, focused on minimizing costs and reducing negative environmental impacts, is becoming increasingly urgent. Automation and electrification are key aspects of this approach, making it possible to modernize agricultural production, increase its efficiency and reduce dependence on external factors. Automation of agricultural processes allows you to control every stage of cultivation, watering and processing of products, which leads to increased productivity and reduced losses. For example, automated irrigation systems with sensors of soil moisture and ambient temperature help to precisely regulate the volume of water supply, which prevents excessive consumption of resources and improves conditions for plant growth. Such systems not only save water, but also significantly reduce labor costs, allowing farmers to manage their farms remotely and with a high degree of accuracy.

In addition, automation reduces dependence on climatic conditions, ensuring stable production even in adverse weather conditions. The introduction of smart control systems using artificial intelligence and predictive models allows processes to be

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adapted to weather changes and plant needs. This is especially important in regions with unstable climatic conditions, where farmers face risks of drought, floods and other natural disasters that can reduce yields [11,96-101].

In addition, automation allows you to manage resources more efficiently and increase productivity. For example, precision farming technologies make it possible to take into account the characteristics of each section of the field and adapt watering, fertilization and other agrotechnical measures to specific conditions. This contributes to a more rational use of resources and reduces the environmental burden, making agricultural production more environmentally sustainable. The use of electrification, in particular, renewable energy sources, reduces energy costs and makes farms less vulnerable to fluctuations in oil and gas prices. In recent years, farms have increasingly introduced solar panels and wind turbines to provide energy for irrigation systems, greenhouses and other agricultural machinery. In the context of rising fuel prices and increasing requirements for environmental friendliness of production, renewable energy sources have become an important component of sustainable agricultural production. Solar energy, due to its accessibility and relatively low installation cost, makes it possible to provide farms with a stable and environmentally friendly energy source. Installation of solar panels on greenhouse roofs, for example, can cover a significant part of the electricity needs to maintain an optimal microclimate. This not only reduces energy costs, but also makes production more environmentally friendly by reducing carbon dioxide emissions. Wind energy has also found its application in the agricultural sector, especially in regions with constant winds. Wind turbines help to provide energy to irrigation pumps and other equipment necessary for the efficient functioning of farms. The use of such technologies makes it possible to reduce dependence on traditional energy sources, which is especially important for remote regions where access to power grids may be limited or unavailable. Despite the obvious advantages, the introduction of automation and electrification in the agricultural industry is associated with a number of challenges. First of all, these are high initial costs for the installation and configuration of automated systems. For many farms, especially small and medium-sized ones, such investments can prove to be a serious barrier. However, the availability of government support and subsidy programs makes technological innovations more accessible, helping to accelerate their implementation. Another challenge is the need for technical support and qualified maintenance of automated systems. Integrated management based on the Internet of Things, artificial intelligence and other technologies requires specific knowledge and skills that not all farmers possess. This creates a need for training and attracting specialists to work with the equipment, which may also require additional costs [3.15].

8.1. The history of the emergence and development of automation in agriculture

Automation of agriculture has a long and complex history, dating back to the 19th century. The evolution of this field has gone through several stages, each of which has brought new technologies and approaches aimed at increasing productivity and reducing manual labor costs. The changes that have taken place over the last century have radically changed the face of agriculture and prepared it for modern challenges related to sustainable development. In the 19th century, the mechanization of agriculture became possible due to the industrial revolution, which led to the development and mass production of the first mechanical devices for cultivating the land and harvesting crops. Before that, agriculture remained mainly a manual and labor-intensive process, limited by production capabilities. One of the first mechanisms were plows, harrows and seeders, which greatly facilitated the work of farmers. It is noteworthy that at this time steam tractors appeared, which were able to replace horses on farms. These machines made it possible to process large areas with less labor and time. An example of a significant invention of that time was the appearance of a threshing machine in 1834, which greatly simplified the process of threshing grain and became an important step towards the mechanization of agriculture. By the middle of the 20th century, agriculture had experienced another stage of technological breakthrough, when the first automated devices designed to perform tasks mechanically were developed. At that time, tractors with motor engines, combines, as well as specialized machines for sowing, processing and harvesting appeared. Mass production of cars became possible thanks to the development of such industrial giants as John Deere and Ford. These companies began to produce tractors and other agricultural machinery, which began to be used by farmers around the world. The availability of technology has made it possible to significantly increase labor productivity and reduce dependence on human power, which is especially important in the conditions of large farms [5,34-39]. In addition to mechanization, the first systems for automatic control of work processes were also actively developed during this period. For example, mechanical irrigation control systems began to be introduced, which made it possible to automate the water supply, ensuring uniform soil moisture.

In the 1980s and 1990s, there was another leap in the development of agricultural technologies, which was associated with the advent of precision farming. The basis for its implementation were geographic information systems (GIS) and the global positioning system (GPS), which allowed farmers to more accurately monitor the condition of their fields and optimize resource allocation. The principles of precision farming involve the use of data on soil conditions, moisture levels, nutrient concentrations and climatic conditions to optimize work in the field. For example, with the help of GPS systems, farmers could automatically control the routes of machinery, ensuring even rows of crops and reducing crop losses due to improper seed distribution.

Precision farming has also led to the emergence of managed systems for fertilization and pesticide application, which has reduced the amount of chemicals used and increased the environmental sustainability of agriculture[6,53-56]. In the 1990s, companies began to develop special software solutions for processing data on the state of fields, which made farm management more centralized and efficient. The programs made it possible to monitor various parameters in real time, which became the basis for the subsequent implementation of automated control systems. In the 21st century, agriculture has entered a new stage of development, where information technologies such as the Internet of Things (IoT), artificial intelligence (AI) and big data analysis have begun to play a key role. These technologies have made it possible to create fully automated systems that are able to control and regulate every aspect of the production process.

The Internet of Things (IoT) is a system that allows you to combine physical devices and sensors into a single network that can collect, analyze and transmit data in real time. In agriculture, IoT has opened up new opportunities to improve process management, increase productivity and rational use of resources. With it, farmers can control and optimize a variety of processes, from irrigation and lighting to monitoring plant and animal health. IoT provides accurate and up-to-date data, which is especially important for improving the efficiency and sustainability of agricultural production [9,78-80].

The use of IoT on farms and in greenhouses In agriculture, IoT sensors are installed throughout the production complex: in fields, greenhouses, storages and on equipment. Here are some common types of sensors and their functions: Temperature and light sensors allow you to maintain the necessary conditions for plant growth. For example, in greenhouses, temperature sensors help regulate heating, ventilation and lighting, ensuring a stable microclimate. Sensors for monitoring plant health record parameters such as chlorophyll levels and nitrogen content in leaves. This makes it possible to identify possible plant diseases in the early stages and take measures to preserve the harvest [12,30]. Weather stations with sensors for air humidity, wind speed, precipitation and other indicators allow you to predict weather changes and adjust plans for irrigation and other activities. Automated irrigation systems integrated with IoT are one of the most sought-after applications in agriculture. IoT systems allow you to start watering automatically based on data on soil moisture, weather conditions and plant needs. This is especially useful for crops that require precise moisture levels, such as vegetables and fruits. Thanks to IoT, farmers can optimize water use, reduce water losses and improve soil conditions. For example, if insufficient humidity is detected, the system automatically activates watering of the desired areas, preventing drought and improving conditions for plant growth. As a result, farmers can save up to 30-40% of water compared to traditional irrigation methods, which is especially important in conditions of water scarcity.

In addition to crop production, IoT is also widely used in animal husbandry.

Sensors mounted on animals can track their location, body temperature, activity level, and even behavior. This data helps farmers monitor the health and well-being of animals, detect signs of disease in a timely manner and prevent the spread of infections. For example, motion sensors can show how active animals are and help identify abnormalities that may indicate health problems. If the cow does not show normal activity or often lies down, this may indicate a disease, and the farmer can promptly call a veterinarian.

In addition, IoT allows you to optimize feeding processes, providing animals with food in the right amount and at the right time. In greenhouse complexes, maintaining a stable microclimate is critically important for plant growth. IoT systems allow you to control temperature, humidity, light level and carbon dioxide concentration. For example, on hot days, sensors can activate ventilation to lower the temperature in the greenhouse, or turn on heaters on cold days to protect plants from freezing. IoT systems also help to regulate the level of illumination, including additional lamps in conditions of insufficient sunlight. In this way, farmers can minimize energy costs by maintaining optimal conditions for crops. Some smart greenhouses are equipped with fully automated systems that control all parameters, including watering, heating, ventilation and lighting, which greatly simplifies plant care and allows you to increase yields [10.76-82].

One of the most significant IoT capabilities in agriculture is analysis and forecasting based on the collected data. The large amount of information coming from various sensors helps farmers make informed decisions, increasing the accuracy of resource management. Data on weather, soil, plants and animals can be processed using specialized software to identify patterns and predict the needs of the farm. For example, based on temperature and humidity data, it is possible to predict when plants will need additional watering or fertilizer. This helps to prevent overdrying or oversaturation of the soil, which has a positive effect on the condition of crops. The analysis of data on the condition of plants and soil also helps to determine the optimal timing for planting and harvesting, which is especially important for regions with a short growing season. IoT actively interacts with technologies such as artificial intelligence (AI), big data analysis and unmanned aerial vehicles (drones). These technologies significantly expand the capabilities of IoT, making agricultural production even more accurate and economical.

8.2. Artificial Intelligence (AI) in agriculture

Artificial intelligence (AI) is becoming one of the key tools for improving the efficiency and sustainability of agriculture. Modern IoT-based systems generate huge amounts of data that can be analyzed using AI to obtain valuable information for managing resources and processes on farms. AI helps farmers make more informed and accurate decisions, allowing them to improve yields, reduce losses and minimize environmental impacts. Thanks to AI, farmers receive not just data, but a whole range of recommendations and forecasts that make their farms more profitable and sustainable. IoT systems collect data on humidity, temperature, illumination, soil composition, plant condition, weather conditions and many other parameters. AI processes this data set to reveal hidden patterns and dependencies. For example, AI systems can analyze long-term climate data to help farmers understand which types of crops are most resistant to local conditions and when it is best to plant. The analysis of patterns allows you to optimize the entire process of growing plants, from planting to harvesting, taking into account the specific conditions and needs of plants. One of the important applications of AI in agriculture is the prediction of plant water and nutrient needs. Based on data on weather, soil moisture, and plant health, AI can determine how much water plants will need in the coming days and weeks. This helps to avoid both excessive watering, which can leach nutrients from the soil and lead to their deficiency, and lack of moisture, which can negatively affect yields. AI can also help the farmer determine when and to what extent fertilizers should be applied. For example, based on data on soil conditions and plant growth rates, AI can predict when plants will begin to experience a deficiency of nutrients such as nitrogen, potassium and phosphorus.

This allows timely fertilization, improving crop quality and reducing fertilizer costs due to their optimal use. AI is able to predict yields based on data on the current state of plants, climate and agrotechnical measures. Such forecasts help farmers plan the season and prepare for harvest, estimating how much produce they will be able to get. Yield forecasts also help farmers make decisions about the sale or storage of products, which is especially important for large market-oriented farms. In addition, AI helps farmers optimally allocate resources, including water, fertilizers and pesticides. For example, the AI can analyze data on the condition of plants and recommend which areas of the field need additional watering or fertilizer treatment and which do not. This reduces resource costs and improves the environmental performance of the farm. Artificial intelligence also plays an important role in monitoring plant health and detecting diseases and pests in the early stages. AI can analyze images of plants taken from drones or cameras and identify signs of disease, such as changes in leaf color or texture. Some systems use machine vision to detect small spots or damage that may be invisible to the human eye, but indicate the presence of infection or pest attacks.

Thanks to AI, farmers can quickly take measures to prevent the spread of diseases and pests, which reduces crop losses and minimizes the use of chemical pesticides. For example, if the AI detects signs of disease in one area of the field, the farmer can limit the processing of only this area, avoiding unnecessary consumption of chemicals and reducing harm to the environment. AI also allows you to automate many tasks on farms, which makes agriculture less labor-intensive and more productive. For example, AI systems can control robots for planting, watering, harvesting and even pruning plants. Such robots can work autonomously, using data from AI to make decisions about when and how to complete tasks. On vegetable and fruit farms, AI robots can harvest ripe fruits, determining their maturity by color and size. Unlike manual harvesting, such systems work faster and more efficiently, which reduces labor costs and improves product quality, since fruits and vegetables are harvested in an optimal state of maturity. AI robots can also carry out sowing and thinning of crops, ensuring a more even distribution of plants and improving conditions for their growth. In Australia, companies use AI to analyze soil and predict wheat yields, which helps farmers plan planting and use resources efficiently. In the USA, farmers are actively using drones with cameras equipped with AI systems to monitor the condition of fields. Drones transmit images that the AI analyzes, determining the condition of plants and identifying potential problems. Robotic systems for picking strawberries and tomatoes have been introduced in Japan, which use AI to recognize the ripeness of fruits and their careful harvesting. This allows you to maintain high product quality and reduce the cost of manual labor. AI can use big data and climate models to analyze the impact of climate change on agriculture. For example, AI can process data on long-term changes in temperature and precipitation levels to predict how climatic conditions will affect yields in the future. This helps farmers adapt to changing conditions and choose sustainable crop varieties that better cope with extreme weather conditions. Big data also helps AI analyze seasonal fluctuations and predict periods of drought or frost, which allows farmers to prepare for extreme climatic conditions and minimize crop losses. This is especially relevant for regions prone to droughts and floods, where risk management is becoming an important part of agricultural strategy. Through precise management and monitoring of plant health, AI helps to increase agricultural productivity and improve product quality. AI allows you to optimize the consumption of water, fertilizers and pesticides, as well as reduce labor costs by automating tasks. AI also helps to reduce the use of chemicals, optimize irrigation and improve the environmental performance of the farm. Climate data analysis and forecasts help farmers adapt their strategies to changing conditions, which is especially important in the context of global warming. The use of AI in agriculture opens up new prospects for resource management, increasing productivity and sustainability of production. The integration of AI with IoT systems and big data analysis allows you to create comprehensive solutions that facilitate process management and reduce risks. In the future, AI will play an increasingly important role in agriculture, helping farmers adapt to climate change, minimize costs and improve environmental performance.

8.3. World experience in the implementation of automation and electrification in the agricultural industry

Agriculture around the world is facing a number of similar challenges, such as climate change, water scarcity, population growth and the need to improve food security. However, approaches to solving these problems vary depending on the conditions and technologies available in a particular country. Let's look at how different countries are implementing automation and electrification in agriculture, based on their unique needs and capabilities.

Israel: the use of drip irrigation systems for efficient water use Israel is one of the world leaders in the use of drip irrigation systems, which has allowed this country to significantly improve agricultural productivity even in conditions of severe water scarcity. The development of precision irrigation in Israel began in the middle of the 20th century, when the country faced an acute shortage of water resources. Drip irrigation, developed by Israeli engineers, allowed water to be supplied directly to the roots of plants, which minimized losses due to evaporation and seepage into the soil [2,45-57]. In addition, thanks to automatic control systems, drip irrigation can be adjusted to optimal volumes of water depending on the condition of the soil and the needs of plants. Today, Israeli farmers widely use IoT technologies to monitor and manage the irrigation system, which further reduces water consumption and increases crop productivity. Technologies developed in Israel are also actively exported to other drought-stricken countries such as India and South Africa, which contributes to improving water use on a global level.

USA: the use of drones and big data for crop management and forecasting The United States, one of the leading agricultural powers, is actively implementing automation, robotics and data analysis technologies to improve the efficiency of the agricultural industry. American farmers use drones to monitor the condition of fields and plants. Drones are equipped with cameras and sensors that record the condition of plants, soil moisture, the presence of weeds and pests. The data collected by drones allows farmers to make decisions quickly and minimize crop losses. Data collection and analysis are also an important component of American agriculture. Farmers use big data and artificial intelligence to predict yields, plan crops, and monitor weather conditions. Such systems make it possible to estimate future harvest volumes and better manage resources. Sustainable agriculture support programs at the U.S. government level promote the introduction of energy-saving technologies, renewable energy sources and automated resource management systems, which help strengthen the resilience of agriculture to climate change. European Union: support for farmers through subsidizing automated systems and renewable energy sources The European Union actively supports the introduction of automation and renewable energy sources in agriculture.

Through programmers such as the Common Agricultural Policy (CAP), the EU provides subsidies to farmers who invest in automated management systems such as smart irrigation, precision farming and robotic assembly systems. These programs are aimed at reducing costs, improving environmental performance and increasing the sustainability of the agricultural sector [14]. The European Union also has strict environmental standards that encourage farmers to use environmentally friendly technologies and reduce carbon emissions. Farmers receive subsidies for the installation of solar panels, wind turbines and biogas plants, which helps them reduce energy costs and reduce the carbon footprint of farms. As a result, farmers can use energy for automated irrigation systems, greenhouse climate control, and other production-related tasks, making agriculture more environmentally sustainable and economically profitable. Japan: the use of robotic systems in crop production and greenhouses Japan, known for its high level of technological development, actively uses robotic systems in agriculture. Due to limited land resources and high population density, Japanese farmers are forced to look for ways to increase yields in limited areas, which has led to the massive introduction of automation and robotization.

In particular, Japan is actively using robotic systems in greenhouses, which makes it possible to create highly productive conditions for growing vegetables and fruits. Automatic harvesters equipped with artificial intelligence systems are used to harvest crops such as strawberries and tomatoes. These robots analyze the maturity of fruits by color and size, which allows you to collect products in an ideal state of maturity. In addition, automatic microclimate control systems are used in greenhouses in Japan: temperature, humidity and lighting. These systems are integrated with sensors and analyze the condition of plants, which allows you to create optimal conditions for their growth. Technologies developed in Japan are also being actively implemented in other countries, as they help significantly reduce labor costs and ensure stable production of high-quality agricultural products. Japanese companies are investing in the development of smart greenhouses and robotic farms that can operate almost without human intervention, which creates opportunities to increase the sustainability of agriculture and expand its capabilities against the background of growing demand for food. World experience shows that automation and electrification of agriculture can significantly increase its efficiency and sustainability. Each country chooses the approaches that best suit its climatic conditions, available resources and economic priorities. The general trend is the desire to use technologies to optimize water and energy resources, improve environmental performance and reduce labor costs. Automation and electrification are the basis for the transition to sustainable agricultural production, capable of responding to the challenges of the modern world, including climate change and population growth.

Conclusion

The Internet of Things (IoT) has become an integral part of the modern agricultural industry, providing farmers with access to new opportunities to improve efficiency, manage resources and improve product quality. IoT technologies combine sensors, controllers, control systems and analytical software, which allows you to create complex automated systems that greatly facilitate the management of processes on farms. Thanks to these systems, agriculture becomes more sustainable, economical and productive. Let's take a closer look at the main advantages that the introduction of IoT brings to the agricultural industry. One of the key advantages of IoT is the ability to accurately manage water and energy resources. In agriculture, irrigation and lighting are processes that require a large amount of resources, especially in arid regions or on farms located in places with limited access to water and electricity. IoT systems help to use these resources efficiently, minimizing costs.

Precise irrigation control: Moisture sensors installed in the soil collect information about the current moisture level and transmit it to the central control system, which analyzes the data and decides when and to which areas water needs to be supplied. Thus, IoT systems can prevent both insufficient and excessive watering by maintaining optimal conditions for plant growth. Optimization of energy consumption: In greenhouses, where significant costs are required to maintain a microclimate, IoT helps to control the lighting and ventilation system depending on weather conditions and the condition of plants. For example, the system can turn off the lighting during periods of high solar activity, which saves electricity. At night, the lighting is turned on at the minimum necessary level to maintain the vital activity of plants without wasting excessive resources. Saving water and energy not only reduces costs, but also reduces the impact of the farm on the environment, which is important for environmental sustainability. IoT systems play an important role in maintaining optimal conditions for crop growth, which helps to increase yields. Thanks to monitoring and analysis of data on soil, climate and plant condition, farmers can quickly make changes to growing conditions, providing plants with everything necessary for their healthy development [7,23-32].

Nutrient monitoring: IoT systems monitor the content of nutrients in the soil, such as nitrogen, phosphorus and potassium, and automatically transmit the data to the management system. This allows the farmer to apply fertilizers in a timely manner and maintain a balanced nutrition of plants, which contributes to their active growth and improvement of product quality [9,45-59] Minimizing the risk of diseases: In conditions where conditions for plant growth are maintained at an optimal level, the likelihood of diseases and damage from pests is reduced. IoT systems can also quickly detect signs of diseases or adverse conditions, which allows you to take action before the problem spreads and leads to crop loss. Increasing yields is especially important in the context of population growth and increased demand for food. IoT helps to meet this demand without the need to increase the area for agricultural land. Automation of processes based on IoT technologies can significantly reduce the need for manual labor, which is a great advantage, especially for large farms and farms with a limited number of employees. IoT helps automate processes such as watering, fertilizing, monitoring plant health and even harvesting, which greatly simplifies the care of crops and animals. Automated irrigation and fertilizer systems: Thanks to IoT, farmers can configure irrigation and fertilizer systems so that they turn on automatically depending on soil condition and weather conditions. This reduces the need for manual management of these processes and frees up workers to perform other tasks. Animal monitoring and feeding management: IoT also plays an important role in animal husbandry. Sensors mounted on animals can monitor their condition and monitor feed intake, which makes it possible to automate and simplify the feeding and care processes. If the system detects a change in the behavior or appetite of an animal, this may indicate a disease, and farmers can take prompt action. Reducing labor costs makes it possible to save money on labor costs and makes the farm less dependent on the human factor, which is especially important in conditions of personnel shortages in the agricultural sector. One of the main advantages of IoT is the possibility of detailed monitoring and control of all processes taking place on the farm in real time. Sensors installed in soil, plants and animals collect data that is instantly processed and analyzed by the control system. This gives farmers accurate information about the condition of plants and animals, which allows them to make informed decisions [4,65-69]. Emergency prevention: IoT helps farmers to respond quickly to any changes in conditions, whether it is a sharp drop in temperature, a decrease in humidity or problems with the condition of plants. The system can automatically alert the farmer or even take necessary actions, such as turning on the heating in the greenhouse when it gets cold or activating irrigation when soil moisture decreases. Long-term planning: Data collected over long periods helps farmers better plan their work and adapt strategies. For example, data on plant water and nutrient requirements can be analyzed to optimize them for future seasons and to anticipate possible changes in conditions.

Improved monitoring and control allows farmers to manage resources more accurately and minimize risks associated with changing weather conditions and other factors. Agriculture is highly dependent on weather conditions, and climate change is creating new challenges for farmers around the world. IoT helps to increase resilience to these changes by providing accurate data and forecasts that enable farmers to adapt to conditions.

Adaptation to extreme conditions:

IoT systems provide farmers with data on current climatic conditions, which allows them to respond in a timely manner to phenomena such as droughts, frosts or heavy rains. For example, a farmer can adjust irrigation and fertilization based on drought forecasts to minimize crop losses. Forecasting and data analysis: The accumulated data allows you to create models and forecasts that help farmers better prepare for climate change. AI systems integrated with IoT can analyze this data and recommend actions to adapt to the expected conditions. Such adaptability helps to reduce losses caused by climate change and maintain a stable level of production, which is especially important in conditions of increasing food demand. IoT allows farmers not only to optimize the use of resources, but also to reduce the impact on the environment. The use of IoT in agriculture contributes to the development of more sustainable and environmentally friendly production methods, which is important for the conservation of ecosystems and the maintenance of biodiversity.

Reducing the use of chemicals: IoT systems help to minimize the consumption of fertilizers and pesticides, as they are used only where and when it is really necessary. This reduces the likelihood of chemicals entering groundwater and minimizes their negative impact on the environment. Reducing carbon emissions: The use of renewable energy sources and energy-saving technologies in combination with IoT helps to reduce greenhouse gas emissions, which helps to reduce the carbon footprint of the farm. IoT systems also help to control energy consumption, which makes agricultural production more environmentally friendly. Environmental sustainability is important for the long-term development of agriculture and the conservation of natural resources for future generations. IoT contributes to the transition to sustainable agricultural

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production, which is becoming an important priority in the context of climate change and population growth [5,45-59]. These six benefits show how IoT is transforming agriculture, making it more efficient, sustainable and environmentally friendly. In the future, the role of IoT in the agricultural industry will only increase, providing farmers with more and more advanced tools for managing and adapting to new challenges. Despite the significant advantages that IoT technology has brought to agriculture, its implementation is associated with a number of serious challenges. These obstacles may limit the use of IoT, especially for small and medium-sized enterprises. The key challenges faced by farmers and agro-industrial enterprises when implementing IoT systems in their processes are discussed below. One of the most significant barriers to the introduction of IoT in agriculture is the high initial costs.

Installation and configuration of IoT systems require significant financial investments, including the purchase of equipment, installation of sensors, implementation of data processing software and employee training. These costs can be significant, especially for small farms that do not always have access to the necessary financing. The cost of equipment and installation: Sensors, controllers, communication devices and analytical software for IoT are not cheap, and installation costs can vary significantly depending on the size and specifics of the farm. The larger the area to cover, the higher the cost of purchasing and installing equipment.

1.Support and modernization: In addition to the initial costs, farmers must also consider the costs of maintenance and modernization of equipment. IoT technologies are developing rapidly and equipment is becoming obsolete, which creates the need for regular replacement of outdated components. These costs can become an insurmountable obstacle for small farmers, who often cannot afford large investments. In some countries, there are support programs for farmers offering subsidies for the introduction of technologies, but access to them is limited and they are not available everywhere.

2. The need for reliable Internet

For IoT systems to work successfully, a stable network connection is required, since IoT sensors and devices exchange data with the central system in real time.

However, in rural areas, especially in remote and hard-to-reach areas, it can be difficult to provide a high-quality Internet connection. This creates serious obstacles to the use of IoT technologies. Lack of network infrastructure: In some rural areas, there is no access to high-speed Internet, which makes the implementation of IoT systems impossible or severely limited. Without a stable connection, sensors can operate intermittently, and data can be transmitted non-operatively, which reduces the efficiency and reliability of the system. Connection and connectivity costs: In regions with low Internet coverage, installing equipment to ensure a reliable connection can become a significant cost item. In some cases, the installation of own communication stations or the use of satellite technologies is required, which further increases the cost of implementation. To solve these problems, there may be prospects for the development of data transmission technologies, such as satellite Internet, or the use of low-power local area networks, but these solutions are not yet available to most farms due to their high cost.

3.The complexity of maintenance and the need for technical support

IoT devices and sensors require regular maintenance and technical support, which may require additional costs and time. Agriculture has its own characteristics, and IoT equipment must withstand difficult operating conditions such as temperature fluctuations, high humidity and dustiness. Regular maintenance: Sensors installed in fields and greenhouses are prone to wear, especially in extreme climatic conditions. To keep the systems in working order, it is necessary to regularly inspect and maintain them, as well as replace worn or damaged parts. This requires time and additional costs, which can be burdensome for farmers, especially during peak season. The need for qualified personnel: The maintenance and management of IoT systems require certain skills and technical knowledge that may not be available to farm staff. In some cases, farmers are forced to hire specialists or contact companies providing technical support services, which increases costs and creates dependence on external contractors. Solving the problem of maintenance complexity requires efforts on the part of equipment manufacturers who can offer more reliable and easy-to-use systems capable of operating in aggressive conditions. Additional opportunities include farmer training programs and the development of self-service technologies that minimize the need for human intervention.

4. Cybersecurity

The collection and storage of data from fields and farms require reliable means of protection against hacking and information leaks, since vulnerabilities in the system can lead to data loss or even the possibility of third-party control of equipment. The introduction of IoT in agriculture makes farms more vulnerable to cyber attacks, which can not only disrupt the operation of equipment, but also lead to financial losses. Data protection: The data that IoT devices collect contains important information about soil conditions, plants, weather conditions, and resource management. A security breach can lead to data leaks and damage to the farm, as the lost information can be used to the detriment of the farm or even by competitors. Remote control risks: If the system is hacked, attackers can gain access to control equipment such as irrigation, lighting and ventilation systems. This can lead to unintended malfunctions, such as excessive watering or equipment shutdown, which will affect the condition of plants and animals [15]. To protect farm IoT systems from cyber threats, regular software updates, the use of data encryption and strong passwords are necessary. However, this requires certain knowledge and skills from employees, which can be an additional challenge. In addition, in most cases, farmers do not have sufficient experience in cybersecurity issues, which makes protecting IoT systems on farms one of the most difficult tasks.

5. Compatibility and standardization issues

Agriculture involves many different processes, and IoT systems must ensure compatibility between different devices and platforms. However, the agricultural industry does not yet have uniform standards for IoT devices, which makes it difficult to integrate various systems. Hardware incompatibility: Different manufacturers of IoT equipment may use unique communication and data transfer protocols, which makes them incompatible with other companies' devices. This makes it difficult to create complex IoT systems where devices from different manufacturers must work together. Difficulties in updating and upgrading: Farmers may encounter a problem when updating or replacing one component requires replacing the entire system due to incompatibility of the new equipment with existing devices. This complicates the modernization and increases the maintenance costs of IoT systems. To solve these problems, it is necessary to implement standards and protocols that will ensure compatibility between devices from different manufacturers. International organizations such as ISO and IEEE are already working on creating standards for IoT in agriculture, but the standardization process takes time. The introduction of IoT in agriculture is accompanied by a number of significant challenges that may limit the possibilities of using this technology, especially for small and medium-sized farms. High initial costs, problems with Internet connection, the need for maintenance, cybersecurity and lack of standards create barriers to the implementation of IoT, requiring an integrated approach to overcome them. Solving these problems will require the participation of various parties, including governments, equipment manufacturers and farmers' organizations, which can develop support programs and provide affordable technologies for all. In the long term, overcoming these challenges will significantly expand the capabilities of IoT in the agricultural industry, making agriculture more sustainable, cost-effective and environmentally friendly.

Automation and robotization of electrical systems in agriculture: prospects and technologies

Modern agricultural enterprises require highly efficient power management to perform tasks such as lighting, ventilation, heating, cooling, and climate control in greenhouses and storage facilities. Effective automation of these processes can significantly reduce energy consumption through the use of intelligent control systems that optimize the operation of equipment depending on current conditions. For example, automated lighting systems equipped with light and motion sensors provide optimal light levels only when necessary, which reduces energy consumption. Climate control systems with integrated temperature and humidity sensors regulate the operation of heaters, fans and air conditioners, maintaining the necessary microclimate and preventing energy overruns. Remote monitoring of electrical systems using Internet of Things (IoT) technologies provides farmers with access to real-time equipment status data. This is especially important for large farms, where the control

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of many facilities can be difficult without automation. IoT devices not only signal system failures, but also allow for preventive maintenance, preventing breakdowns. For example, automatic monitoring of the load level on electrical networks helps to prevent overheating of equipment and emergency situations. In addition, the use of intelligent power systems with peak load management function allows you to redistribute electricity depending on its availability and cost. Such systems may include backup power sources, such as batteries or generators, which ensures uninterrupted operation in conditions of unstable power supply. Modern agricultural enterprises require highly efficient power management for tasks such as lighting, ventilation, heating, cooling and maintaining a microclimate in greenhouses and storages. The integration of automated electrical systems makes it possible to significantly improve energy resource management, minimize losses and ensure optimal conditions for agricultural production. For example, automated lighting systems equipped with intelligent light, time of day and motion sensors adapt the light intensity depending on the need. This is especially important for greenhouses, where year-round production requires strict control over lighting levels. At the same time, circuit breakers prevent unnecessary power consumption in empty areas. Ventilation and air conditioning systems with artificial intelligence elements analyze the current environmental parameters and adjust their work to achieve a balance between energy efficiency and maintaining the required conditions. For example, on hot days, such systems can control the distribution of air flows to avoid overheating of equipment and products, and in cold periods, activate economical heating. Remote control of electrical systems via the Internet of Things (IoT) provides farmers with the opportunity not only to monitor the state of the infrastructure, but also to make changes in real time. This is especially useful for preventing emergencies. For example, if deviations in energy consumption are detected, the system can automatically reduce the load on overloaded sections of the network or switch to alternative energy sources. In addition, intelligent energy management systems allow you to redistribute the load between different parts of the farm, reducing peak energy consumption. This is achieved through a programmable schedule of energy-consuming equipment, which is especially important in the context of rising electricity tariffs. The use of electrical systems is evident in robotic milking machines and feeding systems that operate with a high degree of precision and automation. Such systems play a key role in optimizing livestock production processes, reducing labor costs and increasing productivity. Robotic milking machines are equipped with intelligent sensors that identify each cow, analyze its physiological state and automatically regulate the milking process. This allows you to maintain high milk quality, avoiding damage to the udder, and ensures the comfort of the animals. Thanks to automatic monitoring of the condition of cows, farmers receive real-time data on animal health, which helps to identify possible problems in a timely manner and take preventive measures. Automatic feeding systems are also based on electrical technologies and integrated control algorithms. These systems calculate individual feed rates for each animal based on its weight, age and productivity. The electrical components ensure accurate dosing of feed and its uniform distribution, which minimizes waste and improves the diet of animals. Some systems are equipped with a feed composition analysis function, which helps to adapt nutrition to the current needs of the herd. Integration of artificial intelligence into electrical systems Artificial intelligence has become an integral part of modern agricultural electrical systems. With the help of AI, automated systems can analyze data on soil conditions, plants, weather and animal needs in order to predict energy consumption in advance. For example, AI can regulate the operation of solar panels or wind turbines, ensuring an uninterrupted supply of energy in changeable weather conditions. In addition, AI systems are able to automatically detect the need for equipment repairs, which reduces the risks of downtime and emergencies. The use of renewable energy sources, such as solar panels and wind turbines, is becoming an important element of the robotization of electrical systems. The introduction of autonomous power supply systems makes it possible to ensure the smooth operation of robots and automated installations even in remote areas. For example, on sunny days, electric irrigation systems can be fully powered by solar panels, which significantly reduces energy costs. Despite the obvious advantages, the introduction of automated and robotic systems is associated with a number of challenges. The main obstacle remains the high initial costs of equipment installation and maintenance. In addition, agricultural enterprises often face a shortage of qualified specialists capable of managing and maintaining such systems. Another challenge is to provide a reliable Internet connection for IoT devices, especially in remote areas. Without a stable connection, the systems lose their efficiency, which requires additional infrastructure costs. Automation and robotization of electrical systems in agriculture open up new opportunities to increase productivity, minimize costs and improve environmental sustainability. The integration of innovative technologies with traditional methods makes it possible to adapt the agricultural industry to modern challenges such as climate change and lack of resources. Support for the implementation of such systems at the state level and the development of infrastructure will help accelerate this process, making agriculture more efficient and sustainable.

Prospects and challenges of sustainable agricultural development

Sustainable agricultural development is becoming an increasingly urgent task at the global level, as climate change, population growth and limited natural resources create unprecedented challenges for the agricultural industry. In this regard, automation, the use of renewable energy sources, precision farming technologies and IoT are becoming key elements that can transform agriculture, making it more efficient and environmentally sustainable. Agriculture around the world faces different challenges depending on climatic conditions, economic situation and the level of technology development in each country. However, despite the differences, the prospects for the introduction of advanced technologies in the agricultural industry are obvious for all regions. Countries with highly developed infrastructure, such as the United States, Japan and the European Union, are actively developing automation, robotics and IoT integration on farms. These technologies help to improve resource management, minimize costs and increase productivity. In developing countries such as India, Brazil and African countries, there is also a growing interest in sustainable technologies. Here, the introduction of automation and renewable energy sources helps farmers solve problems related to water scarcity and energy dependence. For example, the use of solar panels for autonomous power supply of agricultural devices allows you to save on electricity and reduces the impact on the environment. Technologies are of particular importance in regions prone to frequent droughts and extreme weather conditions. Here, precision farming based on monitoring soil moisture, microclimate and plant needs becomes an important tool for ensuring food security and adaptation to climate change. Key challenges: investments, qualified services, climate change and access to natural resources Despite significant prospects, sustainable agricultural development faces a number of challenges that limit the pace of technology adoption. One of the most serious obstacles is the high investment costs. The installation of automated irrigation systems, robotic assembly devices and IoT sensors requires significant financial investments that may not be available for small and medium-sized farms. The need for qualified service is also difficult, as modern management systems require specialized knowledge and skills that are not always available to farmers, especially in rural areas. In addition, agriculture remains vulnerable to climate change. Extreme weather conditions such as droughts, floods and temperature anomalies negatively affect agricultural productivity and increase the need for adaptive technologies. However, the introduction of such technologies also requires financial investments and organizational support. Another challenge is access to natural resources, especially water. With the growing demand for food and increasing pressures on water resources, the issue of effective water use is becoming critically important. Precision irrigation technologies and IoT-based water management can help solve this problem, but access to such technologies remains limited for many farmers, especially in low-income regions. Support from Governments and international organizations as an incentive for sustainable development Support from Governments, international organizations and the private sector is needed to accelerate the introduction of sustainable technologies in agriculture. Government subsidy programs and grant support can help reduce financial barriers and increase access to technology for farmers. Programs offering financial assistance for the purchase of equipment or tax incentives can be an important incentive for the transition to more sustainable agricultural production methods. International organizations such as the Food and Agriculture Organization of the United Nations (FAO), the World Bank and the International Fund for Agricultural Development (IFAD) also play an important role in supporting sustainable agriculture. These organizations offer grants and loans to developing countries, finance educational programs and research, and facilitate the exchange of knowledge and technology between countries. In addition, an important factor in the development of sustainable agriculture is the exchange of experience and knowledge. International platforms and conferences, where farmers, scientists and representatives of the private sector share their achievements and best practices, accelerate the spread of innovations and help develop new solutions for agriculture. The prospects for sustainable agricultural development largely depend on the integration of advanced technologies capable of adapting the agricultural industry to new challenges. However, successful technology adoption requires a comprehensive approach that includes financial support, access to educational programs and international cooperation. In the context of population growth and climate change, advanced agriculture should be based on the principles of sustainability, efficiency and environmental friendliness. Automation, robotics, the use of IoT and renewable energy sources open up new opportunities to increase productivity and reduce the impact on nature. Support from Governments and international organizations plays a key role in this process, helping to accelerate the transition to sustainable production methods and ensure food security at the global level.

KAPITEL 9 / *CHAPTER 9* [9]
WINTERING OF CARP IN POLYCULTURE UNDER THE IMPACT OF GLOBAL WARMING IN SOUTHERN UKRAINE

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Introduction

Pond fish farming is the main direction of fishery activities in inland waters of Ukraine. In the conditions of modern climate change and in the conditions of hydrological and hydrochemical regime of ponds, technological parameters, functional status of fish, productivity - all these indicators require review by scientists and practitioners [1, 6, 14, 17]. It is urgent to conduct relevant special scientific research works, experimental studies.

In recent years, fisheries in southern Ukraine have suffered significant losses due to low rates of annual fish hatchery production in the post-winter period. Particular attention is required to the air temperature, which affects artificial water areas with a relatively small area combined with a small volume [6, 7]. This is a characteristic feature of ponds that are part of fish nurseries and full-system warm-water pond fisheries. Against the background of an increase in the growing season, the winter period has shortened, and the winters themselves have become less cold, which accordingly affects the effectiveness of overwintering of fish seedlings [26, 27].

Today, in the scientific and practical literature, authors note the importance of harmonizing biological and technological parameters in fisheries and aquaculture. They pay attention to adaptogens, biological components of natural nature, optimization of juvenile rearing technology, etc. [8, 12, 15]. Modern factors, including climate change, technogenic load - all this has a negative impact on the ecosystem, indicators of ontogenesis of aquatic organisms, their productivity, development, physiology and other indicators [25, 10, 11]. Experience in optimizing technological conditions in fish farming demonstrates that a positive result can be obtained if the technological scheme is comprehensive, providing for all abiotic and biotic conditions [8, 9, 22, 23, 28].

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9.1. Aspects of the regional context

For the Southern part of Ukraine, when conducting fisheries activities, it is important to follow the recommendations based on the characteristics of climatic parameters [23, 28]. The location in the continental region of the temperate climate zone is characterized by a temperate continental climate with a mild, unstable winter and hot, dry summer. Such a climate is formed under the influence of a complex of factors. The magnitude of total solar radiation depends on the geographical latitude. The formation of the climate of the Kherson region is greatly influenced by the location of the region in the low pressure belt of temperate latitudes, the dominance of temperate (marine and continental) air masses, as well as cyclones of the Black Sea, Atlantic and Mediterranean Sea. In this case, it is important to take into account the influence of the Azov anticyclone [2, 24].

The steppe zone of our country is characterized by a moderately warm climate with insufficient moisture. At the same time, the soil is characterized by diversity. There are both sandy and peaty areas. The annual radiation balance is 50-57 kcal/cm. The duration of the growing season is 210-245 days. With the warmest month of July (when the average monthly temperature is 23-25°C, and the maximum temperature is 38-41°C). In January, the temperature is on average 7°C. The number of days with a temperature above 15°C is 120-130 [16]. The coldest month in the growing season is September (with an average temperature of 14.8°C). In contrast, the warmest month is July (when the thermometer shows 23°C). The average annual air temperature is 10°C with the sum of temperatures from May to September 2801-3182°C. The average annual precipitation varies from 300 to 600 mm, evaporation from 700 to 1000 mm [3, 5, 27].

Thus, the Kherson region has a continental type of annual precipitation, in which the amount of precipitation in the warm period is 300-400 mm, with evaporation from 1000 to 1050 mm (prevails over the amount of precipitation in the cold period).

The duration of the growing season is from 215 to 225 days, and without frost, from the last frost in spring to the first in autumn - from 175 to 180 days [16, 23].

The practical base for the implementation of complex works - the Kherson Production and Experimental Plant for Breeding Young Partial Fish - is located in the continental region of the climatic zone of Ukraine of temperate latitudes. It is characterized by a temperate-continental climate with mild, short-lived winters and hot, dry summers.

9.2. Technological aspects

The regulatory basis for the development of a set of measures was: the Law of Ukraine "On the Animal World"; Instructions on the procedure for artificial breeding, growing fish, other aquatic living resources and their use in special commercial fish farms; Instructions on the procedure for special use of fish and other aquatic living resources; Instructions on the procedure for carrying out work on the reproduction of aquatic living resources, etc. Hydrochemical, morpho-physiological studies were carried out according to generally accepted methods. Wintering ponds in fish farms of the Southern region of Ukraine are used for different age groups of heat-loving fish species, namely yearlings of carp and herbivorous fish. Nowadays, the vast majority of farms implement the process of wintering yearlings based on outdated existing standards.

Given that modern conditions are significantly transformed, the features of southern Ukraine against the background of the current general warming of the atmosphere, turned out to be the most sensitive to the wintering of this year's carp fish. It is important to take into account the outlined aspects, including that the water temperature for hydrobionts (carp in polyculture when growing and breeding especially in ponds) plays a key role in the intensity of their development in ontogenesis and other biological processes.

It should be noted that modern insufficiently cold winters, the absence of ice formation provoke fish that winter to active behavior. As a result, this leads to the loss of reserves of the fish organism, their exhaustion, and as a result, an increase in the departure of fish after wintering.

When forming the experimental groups, the recommended regulatory data on the density of carp planting in polyculture for the Southern region of Ukraine were taken into account and based on (Table 1).

Table 1. Fish wintering standards

Indicator, units of measurement	**Type of fish**	**Polissya** *(III)*	**Forest-steppe** *(IV)*	**Steppe** *North (V)*	**Steppe** *South (VI)*
Wintering ponds: area, ha depth of the non-freezing layer, m		0,5 – 1,0 1,2	0,5 – 1,0 1,2	0,5 – 1,0 1,2	0,5 – 1,0 1,2
Water exchange, day		15-20	15-20	15-20	15-20
Planting density of annuals, thousand specimens/ha	C*	600	650	700	450
	P*	450	450	500	550
The emergence of annuals from wintering ponds, %	C*	75	80	80	85
	P*	75	80	80	85
Mass losses during wintering, %		12	12	11	10

* Polyculture: C (*carp*) - *Cyprinus carpio; P (*polyculture*) - Ctenopharyngodon idella, Hypophthalmichthys molitrix / Hypophthalmichthys nobilis*

9.3. Practical part of the work

The objects of research are presented in the following Fig. 1.1. Based on the characteristics of the farm's pond areas, it should be noted that the enterprise is a fish hatchery, an enterprise that effectively stocks the reservoirs of the Lower Dnieper.

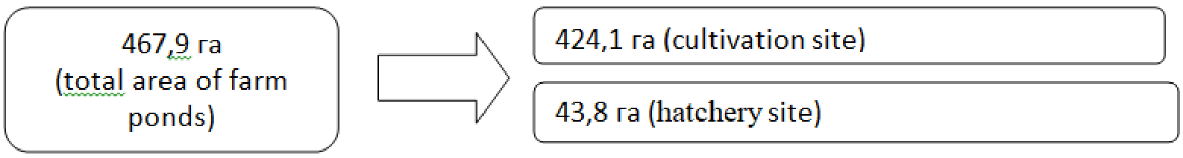

Figure 1.1 - Characteristics of the practical basis of experimental research

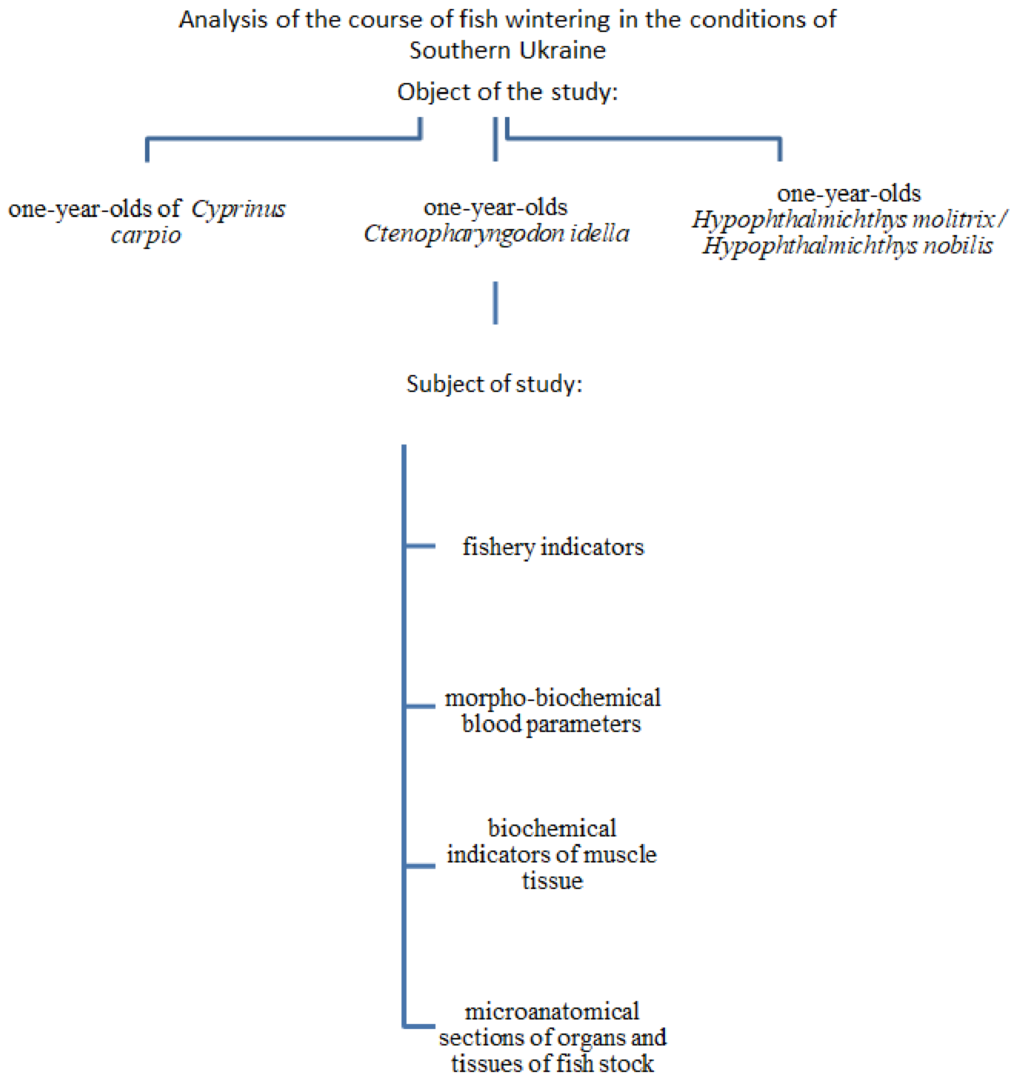

Figure 1 - Algorithm and research basis

The pond fund includes all land plots that are used and occupied by artificial reservoirs intended for certain technological processes. The fishery includes a growing and hatchery area, an incubation workshop with a capacity of 45 million pieces larvae, water supply, discharge and drainage pumping stations, as well as two boiler houses. The research was conducted on the basis of the above-presented fishery of the State Enterprise "Kherson Experimental Production Plant for Breeding of Young Partridge Fish" (Ukraine). Monitoring of the leading parameters was carried out using generally accepted methods in fish farming, hydrochemistry, and physiology [4, 19, 20]. Histological analysis was performed using the author's method (Kozy M.S., 2009) [13, 21]. Laboratory conditions were used, as well as a professional weather station

Ambient Weather AW007 with the UC20GC-128 STD module.

9.4. Main results and discussion

The dynamics of degree-days demonstrates a typical temperature pattern for the south of Ukraine, but not optimal, but significantly higher for wintering in carp ponds of the southern region.

After wintering, losses in linear-weight sizes during the winter period were within 18 - 32%, but the yield and survival after wintering in the middle group for all species was lower than in fish with a "large" size. This difference can be explained by a larger reserve reserve in fish and, accordingly, better metabolic processes, their physiological state.

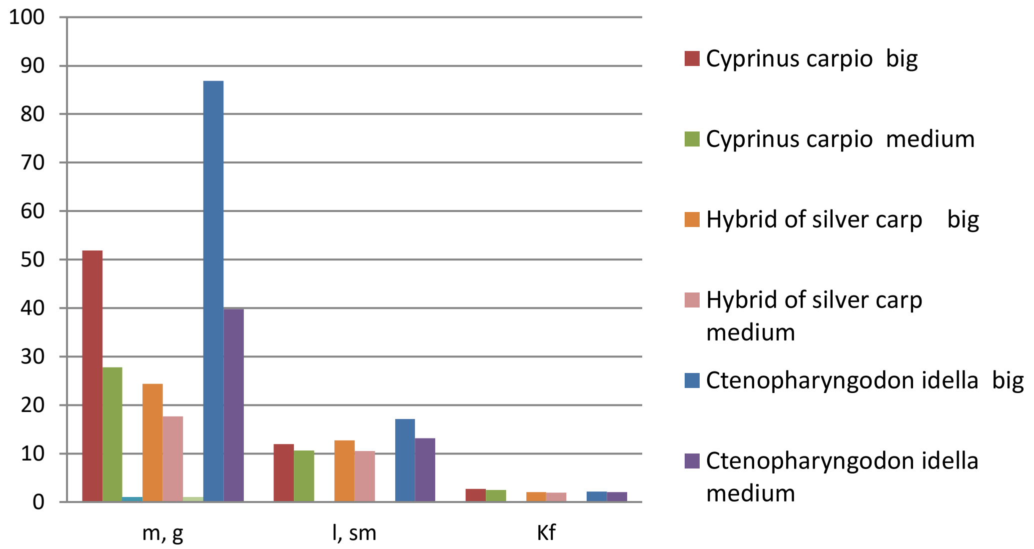

Figure 2 - The effect of wintering on linear dimensions (l, cm; average body weight, g) and fattening coefficient Kf in cyprinids before winter

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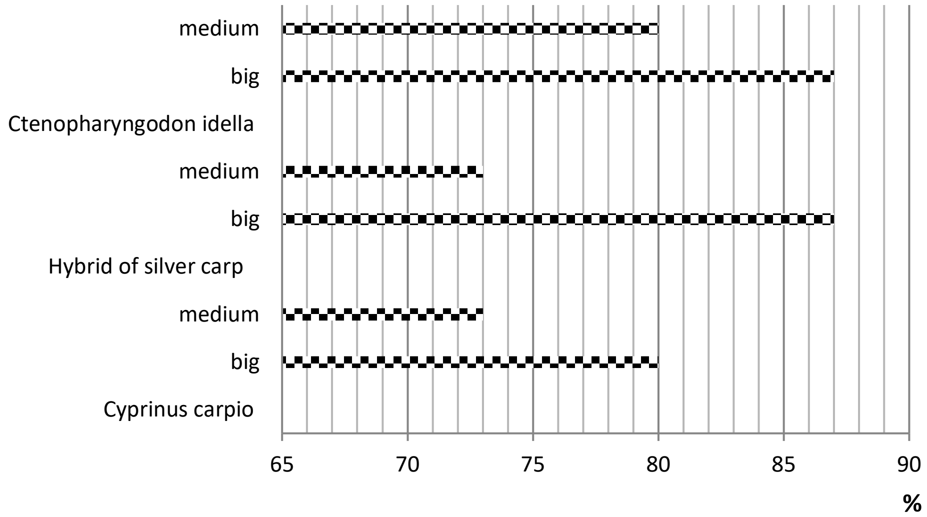


Figure 3 - Survival after wintering, %

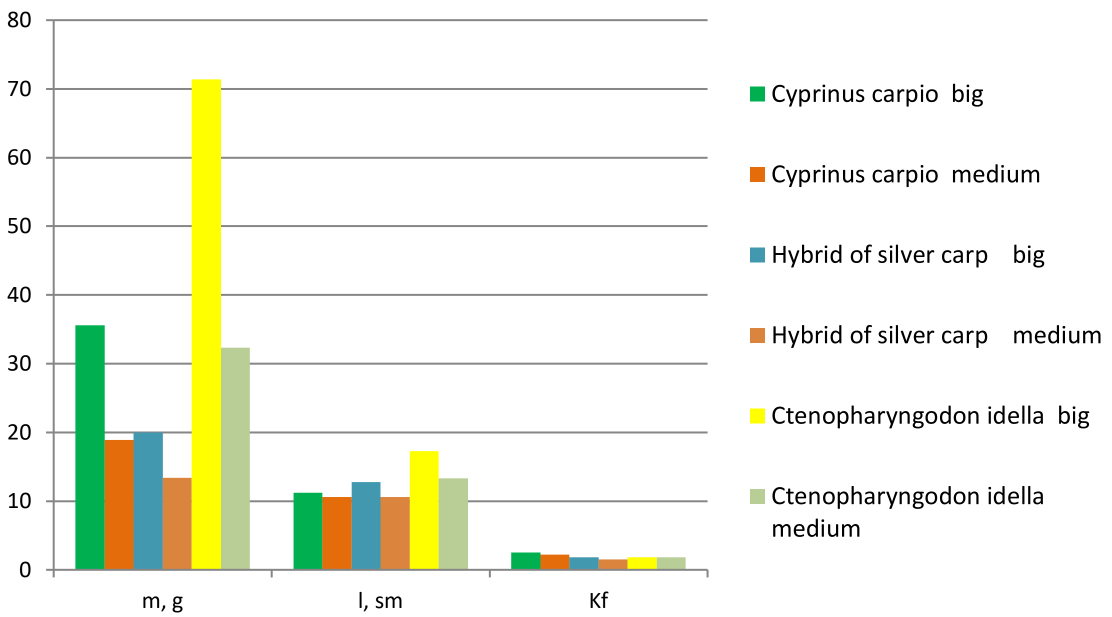


Figure 4 - The impact of fish wintering on linear measurements after wintering

Analyzing the trend of changes in blood composition parameters in fish depending on the influence of the seasonality factor, we can conclude that metabolism and synthesis processes influenced the rate of fish development. Homeostasis parameters corrected the rate of body weight loss, as well as its accumulation during wintering. The percentage of fish survival was also correlated. It is important to note that physiological and biochemical parameters had a direct and indirect effect on the morphometric, meristic and plastic indicators of fish. The content of total protein before wintering in fish was a minimum of 15.25 and a maximum of 24.36 g/l (Table 2,3). Seasonality and all related factors contributed to a greater decrease in this indicator after wintering, on average by 5.55%.

Table 2. Analysis of the blood composition of carp in polyculture before winter, X ± SD, n=12

Parameters	*Cyprinus carpio*		*Hypophthalmichthys molitrix / Hypophthalmichthys nobilis*		*Ctenopharyngodon idella*	
	big	medium	big	medium	big	medium
Total protein, g/l	22,38±0,98	23,15±0,90	20,16±0,56	16,46±0,75	24,36±1,16	15,25±0,90
Albumin, g/l	6,49±0,36	6,01±0,28	5,72±0,33	5,76±0,75	6,48±0,74	9,40±0,68
Creatinine, mg/dl	0,09±0,01	0,08±0,01	0,07±0,01	0,30±0,02	0,10±0,01	0,35±0,01
Triglycerides, mg/dl	139,68±6,68	134,89±10,13	131,99±2,80	69,52±0,92	142,49±2,97	51,35±4,49
Cholesterol, mg/dl	141,03±10,06	126,44±11,78	120,10±0,85	108,29±15,62	118,48±3,16	129,92±1,78
Calcium / Phosphorus, mg/dl	7,69±0,18/ 18,84±1,40	7,61±0,19/ 20,25±1,30	6,78±0,29/ 12,70±0,37	6,93±0,35/ 13,83±0,66	7,66±0,33/ 13,50±0,40	4,85±0,37/ 16,83±0,49

Table 3. Analysis of the blood composition of carp in polyculture after wintering X ± SD, n=12

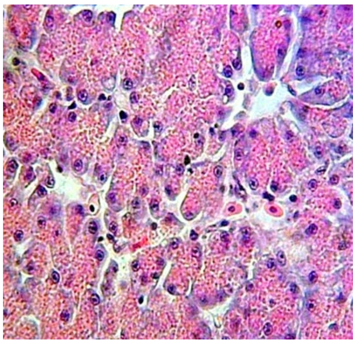
Parameters	*Cyprinus carpio*		*Hypophthalmichthys molitrix / Hypophthalmichthys nobilis*		*Ctenopharyngodon idella*	
	big	medium	big	medium	big	medium
Total protein, g/l	22,25±1,29	21,25±1,03	21,86±1,15	18,70±0,82	23,72±2,27	14,15±1,21
Albumin, g/l	16,71±3,24	23,65±3,92	6,73±0,50	5,88±0,16	6,13±1,05	9,87±1,69
Creatinine, mg/dl	0,35±0,01	0,34±0,08	0,10±0,01	0,30±0,01	0,10±0,01	0,28±0,02
Triglycerides, mg/dl	125,57±3,56	128,00±3,49	124,47±1,20	65,08±4,58	141,01±1,91	48,76±1,05
Cholesterol, mg/dl	103,28±7,79	100,31±6,57	114,39±5,45	72,34±0,85	116,24±2,27	121,79±15,84
Calcium / Phosphorus, mg/dl	6,63±0,49/ 11,34±0,22	5,22±0,40/ 11,50±0,15	5,55±0,27/ 12,24±0,80	6,37±0,55/ 7,86±0,52	5,73±0,77/ 12,77±1,62	2,73±0,20/ 16,42±0,49

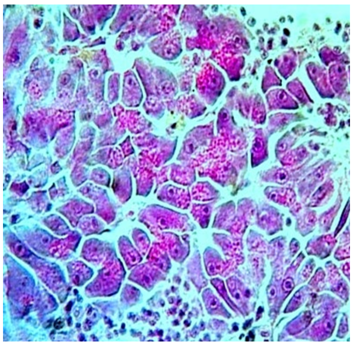
The moisture, protein and ash content was at the optimal level to ensure the physiological needs of the fish. The fat percentage did not meet the recommendations. After wintering, a natural increase in the moisture and ash content in the muscles of all groups of carp in polyculture was observed.

In the body, protein loss in "large" fish was within the limits: for carp - 18%, for hybrid silver carp - 29%, and for white grass carp - 12%. Analysis of fish with an "average" size showed that in yearling carp this parameter was 23%, for hybrid silver carp - 35%, while for white grass carp this parameter was 22%.

Fat loss in yearlings of the large group was within the limits: carp – 39%, hybrid silver carp – 44%, grass carp – 35%; in yearlings of the medium group: carp – 49%, hybrid silver carp – 51%, grass carp – 49%. When comparing the fat content in the muscles before and after wintering, an activation of metabolic processes was also noted.

Analysis of histological parameters demonstrated that during the wintering period, specific processes occurred in the fish body. A decrease in the activity of gland secretion was noted, which also corrected the activity of the fish digestive systems. In this case, this was most clearly seen in the structure of the hepatopancreas of the Ctenopharyngodon idella (Fig. 5).





1 2

Figure 5 - Analysis of structural parameters of the hepatopancreas of Ctenopharyngodon idella before the beginning of wintering (1) and after wintering (2). Boehmer's hematoxylin, Hart's fuxelin (modified). Correction filter "ZhZM 2.5X" (1), "MONOCHROM 2.5X" (2), X200

Analysis of the figure provides grounds to note that the cells that form the terminal sections of the exocrine part of the grass carp organ are tall and cone-shaped. Their nuclei are rounded, oriented towards the basal part of the cells. The apical ends of the cells are oxyphilic, and the basal ends acquire the tone of the main dye. The terminal section and lobules of the gland are surrounded by layers of loose connective tissue.

Among the characteristic features of exocrinocytes (acinocytes) of the hepatopancreas is a peculiar "foaminess" of the cytoplasm, which is observed in their apical part. The specific type of cells is due to the fact that proteinases and lipases are secreted when they are in an active form. In pancreatic exocrinocytes, theyproteinases and lipases have the form of zymogen granules. The established characteristics are characteristic of fish in optimal conditions of existence, without stress factors. In the winter period, the intensity of zymogen biosynthesis is significantly reduced, as a result of which the homogeneous pole of acinocytes prevails over zymogens. Wintering is a peculiar factor as a stress [18].

The specificity of the structure of the mesonephros and its functioning in fish are associated with the peculiarities of osmoregulation in a certain period of the season, which is regulated against the background of changes in the physicochemical parameters of the environment. The structure of the mesonephros of fish in wintering conditions is shown in Fig. 6.

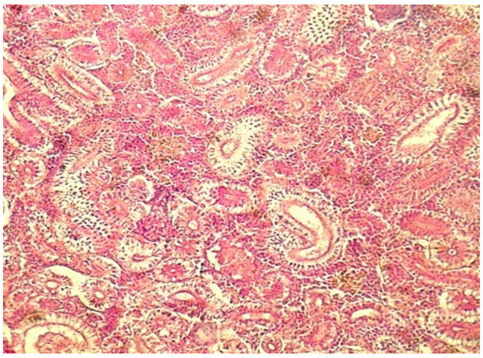


Figure 6 - Mesonephros of annuals Hypophthalmichthys molitrix / Hypophthalmichthys nobilis in wintering conditions Boehmer's hematoxylin, Hart's fuxelin (in modification). X120

The space between the leaves of the Bowman-Shumlyansky capsule is narrow, which indicates the presence of a small volume of primary filtrate in the capsular cavity. The discovered fact indicates the ability of the nephron to smoothly compensate for water losses from the body, which is characteristic of peak seasonal changes in oxygen and temperature. In this case, this is the wintering of fish.

Summary and conclusions

The dynamics of changes in air and water temperature against the background of other meteorological parameters provides an opportunity to more comprehensively assess the impact of global warming on the wintering of carp fish in the conditions of ponds in southern Ukraine. The temperature of the pond water during the wintering of carp fish was within 4.48°C - 5.69°C. At the same time, the minimum values of water temperature were recorded in January, and the maximum in October.

Against the background of air temperature in October and minimum in February. The dynamics of degree-days demonstrates a typical temperature pattern for the South of Ukraine, but not optimal, but significantly higher for wintering in ponds of carp fish of the Southern region of our country.

The results of the studies demonstrate the negative impact of wintering and the reduction of winter temperature ranges on the morphofunctional state in the body of fish stock in the conditions of ponds of southern Ukraine. The reason for this may be the general warming of the climate of southern Ukraine by 1.2 - 1.5^{0}C. Under these conditions, the fish were in the optimal wintering temperatures of adaptive and compensatory mechanisms for one month. At a range of wintering temperatures above the optimal ones, fish stock of carp fish species actively spent nutrient reserves against the background of body weight loss and general exhaustion, which negatively affected the physiological and biochemical indicators of blood, muscle part and microlevel changes in fish organs and tissues.

The results obtained confirm the impact of climatic transformations on the general physiological state of the organism of carp *(Cyprinus carpio)* fish stock in polyculture with herbivorous fish: grass carp and hybrid silver carp *(Ctenopharyngodon idella, Hypophthalmichthys molitrix / Hypophthalmichthys nobilis)* during the wintering period. The emphasis is on the conditions of southern Ukraine. It was established that the recorded changes in air temperature during the winter correlate with the temperature and oxygen regime of wintering ponds. Against this background, there is an impact on the main fishery indicators of this year's and one-year-old carp in polyculture with herbivorous fish. The main fishery indicators of fish change, including the fattening coefficient, the percentage of fish survival after wintering, and morphometric indicators.

The results are supplemented by a biochemical analysis of muscle tissue, blood, and histology of fish organs and tissues.

A new concept of optimizing the technological aspects of growing young fish, fish stock is proposed. The emphasis is on optimizing the course of wintering of carp and herbivorous fish, taking into account the reduction of the ice-free period on wintering ponds. Simultaneously with the use of increased fish stocking density, there is an overtime consumption of nutrient reserves in their body. The results are confirmed by biochemical parameters, blood composition, and histological analysis.

Optimization of the technological process, which consists in changing the technology of growing fish stock from a two-year turnover to a one-year one, excluding the wintering period in artificial wintering ponds from the technological process, which under modern climatic conditions of southern Ukraine negatively affects the physiological state, fishery indicators and economic efficiency of the production of introduced fish for further stocking of natural water areas.

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