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FOOD PRODUCTION: INNOVATIVE TECHNOLOGICAL SOLUTIONS

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The collective monograph presents material on modern scientific and practical aspects of the development of innovative technological solutions in the field of food technology. The scientific publication presents the results of the following scientific research in the following areas: the development and market promotion of enteral nutrition products for herodietic purposes, the production and use of special dietary milk A2, obtained by enriching it with carrot powders, and certain types of dairy products made on its basis, the implementation of innovative resource-saving methods of production of polycomponent semi-finished products with a high degree of readiness for food products, in particular, a hardware-technological production line that can to be located directly on farmlands for the cultivation of natural raw materials, the organization and implementation of pastoral activities in Ukraine, the results, status and priorities of its management to ensure the food needs of the population.
The publication is aimed at a wide range of readers, in particular specialists in the field of production, processing, sale and other stages of ensuring the market circulation of various types of food products, scientists, other specialists, direct consumers of food products, students.
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ABSTRACT

In the presented material of Chapter 1, it was analyzed that the share of persons belonging to the representatives of older age groups in the general structure of the Earth's inhabitants in 2025 will reach the level of 20 %. Ukraine is also one of the countries characterized by significant rates of population aging. The essence of the aging process, the changes that occur in the body during this process, in particular in emergency situations, including with physical and nervous overloads, somatic diseases, injuries. The prospect of conducting scientific developments to provide opportunities for target consumers of this product, including on national markets, to choose from an expanded range of products of appropriate quality. The studied results create a basis for the development and production of both ingredients and products for enteral nutrition of persons of older age groups, paying attention to the creation of appropriate conditions for ensuring the health of the population.

Chapter 2 presents the results of the scientific substantiation of the feasibility of using dietary A2 milk, obtained by enriching it with carrot (Daucus carota) powders, and its advantages. In particular, it has been investigated that the use of carrot powders allows to improve the amino acid composition of milk, to significantly ensure the body's daily need for essential amino acids. The perspective of using this milk in cheese making has also been established.

Chapter 3 presents the scientific justification and analysis of the proposed resource-saving method of production of polycomponent puree-like semi-finished products of a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, red beet and hawthorn was carried out. It has been substantiated that the hardware implementation of the proposed method is provided by the author's developed designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, ensuring uniformity of heat supply, stabilization of the temperature range, the possibility of using secondary heat energy.

Chapter 4 presents data on the current state of production of agro-industrial raw materials, the share of animal husbandry in it, its socio-economic significance, and the importance of development for ensuring the nutritional needs of the population of Ukraine. The presented material established that the share of beef consumption by Ukrainians as a source of complete protein and certain vitamins is insignificant. Data on the consumption of beef by the population of Ukraine in recent years and the reasons for the decrease in this indicator are also given.

KEYWORDS

Products for enteral nutrition, herodietetic purpose, emergencies, elderly people, aging, metabolic activity, diabetes, raw components, approaches to classification, milk A2, hard cheeses,

enriched milk A2, carrot powder, milk carotenoids, amino acids of milk, β-casein A2, biological value, cheese yield, milk proteins, functional products, multicomponent semi-finished products of a high degree of readiness, mechanism of competitiveness, concentration, drying, resource saving, film-like electronic heater of radiating type, structural and mechanical indicators, temperature field, cattle breeding, food safety, beef, quality of consumed protein.

CIRCLE OF READERS AND SCOPE OF APPLICATION

The results of scientific research, presented in this collective monograph, are quite important for ensuring food security of the population in general, creating appropriate conditions, improving them to meet the nutritional needs of consumers, increasing the level of safety and quality of products, establishing and optimizing technological solutions in the process of cultivation, during production, packaging, storage, transportation, sale of the offered food products, their presentation in trade establishments, restaurants, catering and medical institutions, other objects.

The material related to the merchandising aspects of the development and market promotion of food products for enteral nutrition of herodietic purpose can be used by medical professionals, in particular, herodietists, therapists, surgeons and other specialists in the treatment of closed conditions, in the elimination of metabolic disorders in the body of persons belonging to the elderly groups caused by emergency factors, directly by representatives of older age groups, their relatives and relatives to create more optimal conditions in the process of eliminating physiological imbalances, by production entities, representatives who are engaged in the supply, sale, distribution of food products for special medical purposes.

Information on the technological features of production, indicators that determine the increased nutritional, in particular biological, value of A2 milk obtained by enrichment with carrot powders, its advantages, prospects for use in the production of other dairy products, in particular hard cheeses, can be quite useful for representatives of organizations that engaged in production, provision of market promotion and other stages of the life cycle of food products, directly to consumers, especially those who care about a healthy lifestyle, nutritionists, fitness trainers and other persons.

The results of scientific research on the developed resource-saving method of production of polycomponent puree-like semi-finished products of a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, red beet and hawthorn should be quite interesting for persons engaged in the development of special technological lines for the production of special food products, business investors – for projects, engineers, representatives of the restaurant, in particular catering, business, organizations for the production of craft products and many others persons.

The material concerning the state and prospects for the development of cattle breeding in Ukraine should be particularly relevant for representatives of the meat processing sector, economists, industrialists, participants in the agricultural market, in particular those engaged in breeding and slaughtering cattle, subjects of trade in these products, consumers, representatives of science, executive authorities.

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INTRODUCTION

According to FAO/WHO, the number of starving people in the world is rapidly increasing and currently has more than 1 billion people. It is predicted that the long continuation of the war in Ukraine will contribute to the escalation of global hunger and poverty. Thus, there is a threat to stability and food security both at the global and regional level. The results of these negative phenomena can be especially noticeable for the countries of Africa, Asia, and Eastern Europe.

According to USAID, in order to adequately meet the food needs of the world's population, which is expected to grow to 9 billion people by 2050, it will be necessary to double the current production of food products. In particular, FAO/UN experts note that food security can be considered sufficient if all people at any time have physical and economic access to a sufficient amount of safe and nutritious food resources that will meet their needs and provide the opportunity for an active and healthy life.

The listed and analyzed information and data regarding the issues of achieving food security and adequate provision of food needs determine the importance of conducting modern scientific research in the field of food technology, in particular, the development of innovative technological solutions in this field. Thus, this collective monograph, consisting of 4 chapters, presents the results of scientific research in the declared field, which make it possible to solve important socio-economic tasks to meet the nutritional needs of the population.

Chapter 1 Marketing aspects of development and promotion of products for enteral nutrition for herodietical purposes presents the results of scientific research on the merchandising aspects of the development and market promotion of enteral nutrition products for herodietic purposes, which are specially designed for the elderly and are aimed at meeting their nutritional needs in emergency situations.

Chapter 2 Justification of the feasibility of using A2 milk in the production of some dairy products presents the results of scientific substantiation of the feasibility of using dietary A2 milk, obtained by enriching with carrot powders, which significantly contributes to increasing the nutritional value, in the production of certain types of dairy products, in particular hard cheeses.

Chapter 3 Scientific and practical justification of innovative approaches to production of multicomponent semi-finished products for food products in the conditions of food security of the country offers information on scientific and practical substantiation of innovative resource-saving methods of production of multi-component semi-finished products of a high degree of readiness for food products in the conditions of food security of the state. In particular, the material provides data on the developed hardware-technological line for the production of vegetable polycomponent semi-finished products of a high degree of readiness, which can be located directly on farmland for the cultivation of natural raw materials, the advantages of its use.

Chapter 4 Cattle breeding in Ukraine as one of the indicators of food security presents data on the current state of production of agro-industrial raw materials, the share, significance and importance of the development of animal husbandry in the system of ensuring the nutritional needs of the population of Ukraine, its consumption of beef, information on the factors that have caused a decrease in its consumption by the population of Ukraine in recent years.

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MARKETING ASPECTS OF DEVELOPMENT AND PROMOTION OF PRODUCTS FOR ENTERAL NUTRITION FOR HERODIETICAL PURPOSES

ABSTRACT

The current global demographic structure of the population at the global and national levels indicates significant rates of aging. As a result of this process, gradual metabolic changes appear in the body, characterized by a slowdown in metabolic processes, the level of assimilation of oxygen and nutrients, and a decrease in the body's functional capabilities. Nutrition is one of the main factors that ensure the vital activity of the human body. The completeness and correspondence of the food ration to the metabolic needs makes it possible to significantly influence the level of health and physiological state. Adherence to nutrition is important for older people, and especially in emergency situations arising from psycho-emotional and physical stress, diseases and injuries, in the process of rehabilitation and recovery. In connection with this, the practice of consumption (use) of products for enteral nutrition, which according to international legislation are considered dietary food products for special medical purposes, has become widespread. The paper analyzes general approaches to ensuring the nutritional needs of representatives of older age groups. Based on this, it was established that for their full satisfaction, physiological processes due to changes in metabolism during aging should be taken into account. It has been established that the elderly, senile and long-lived people need a balance of the main nutrients, namely an increased amount of protein and lipid components and a reduced amount of carbohydrates, adequate supply of vitamins and minerals. As a result of the study of nutritional needs of representatives of older age groups in emergency situations, it was established that their full satisfaction largely determines the success of treatment and rehabilitation, requires taking into account the specifics of metabolism and dietary principles. The peculiarities of the needs of representatives of this category of people who additionally suffer from diabetes, which requires restriction of carbohydrate consumption, were also studied. It has been established that enteral nutrition products are used to meet their nutritional needs. The work describes the main and additional raw components used in the production of products for enteral nutrition. The existing approaches to the classification of the studied products were also investigated, a classification was developed that reflects technological and consumer characteristics and is aimed at satisfying the interests and preferences of the target category of their consumers.

KEYWORDS

Products for enteral nutrition, herodietetic purpose, emergency situations, older people, aging, metabolic activity, diabetes, raw components, approaches to classification.

Widespread trends observed today, both at the global and national levels, are the increase in the average age and the aging of the population. These facts are evidenced by the results of research by the United Nations (UN) [1] and the World Health Organization (WHO) [2] regarding the increase in the average age of the world's population. According to the forecasts of specialists of these organizations, the share of people belonging to older age groups (age 60 and over) in the total structure of the Earth's inhabitants in 2025 will reach the level of 20 %. It is also assumed that in 2050 it will increase even more and will amount to about 30 % (2 billion people). It is appropriate to note that Ukraine is one of the leading countries (among the top 10) in terms of the overall rate of population aging [3]. Thus, in this state, the number of people aged 60 and over in 2021 exceeded 10 million, which is more than 25 % of the overall age structure.

The natural physiological aging of the body is characterized by a number of metabolic changes, in particular, a gradual slowing down of metabolic processes, the level of absorption of oxygen and nutrients, a decrease in the functional capabilities of systems, organs, tissues and cells. It is a scientifically proven fact that aging processes largely cause degenerative changes and diseases of the cardiovascular, nervous, locomotor, digestive and other systems of the body. These processes take on a particularly negative character in emergency situations, in particular during physical and psycho-emotional overloads, stressful events, diseases, injuries, in the process of rehabilitation and recovery.

It is natural that food is rightfully considered one of the main factors that ensure the vital activity of the human body. The completeness and compliance of the food diet with metabolic needs makes it possible to significantly influence the level of health and condition of a certain person, to a certain extent to correct physiological disorders. Macro- and micronutrients that enter the body with food from the external environment actively affect the course of metabolic processes, the state of the immune, nervous, digestive systems, etc. Taking this into account, the consumption of food products for herodietic purposes has become widespread in modern practice, which, according to the wording developed by specialized specialists of the WHO, are defined as "products intended for consumption (consumption) by persons belonging to older age groups, which have been specially developed, processed and/or produced in accordance with the specific nutritional needs of the body of representatives of this category of people and take into account the specifics of their metabolic processes" [4].

The full value of providing nutrients, which in terms of qualitative and quantitative composition will correspond to the specifics of age-related changes and the nutritional needs of the body, in emergency situations becomes especially important for representatives of older groups. In view of

this, in order to ensure the nutritional needs of representatives of older age groups, in particular in emergency situations, the consumption (use) of products for enteral nutrition has become widespread in modern practice. According to the terminology developed by specialists of the European Society of Parenteral and Enteral Nutrition (ESPEN), enteral nutrition is defined as "a method of providing the nutritional needs of the body with optimal complete nutrition through the use of a specially defined and prepared food mixture through the gastrointestinal tract" [5]. Products for enteral nutrition, which according to international legislation belong to dietary food products for special medical purposes [6], are characterized by a specially selected, scientifically based composition of components. Thanks to this purposefully modeled to ensure the defined functions of the composition of nutrients, these products allow to better meet the needs of the body, contribute to the optimization of the physiological state, increase of immune and restorative properties.

Taking into account the significant number of older people, their vulnerability to diseases, injuries, increased stress levels, factors causing emergency situations, the urgent task is to provide products for enteral nutrition of herodietic purpose. It should also be noted that the products of this assortment group are presented on the modern market in a rather limited assortment. This, in turn, determines the prospect of conducting scientific developments to enable target consumers of these products, including on national markets, to choose from an expanded range of products of appropriate quality. Considering the above, it is necessary and important for development in this direction to study the merchandising principles of creation and marketing promotion of products for enteral nutrition of herodietic purpose. It is important to note that in order to effectively achieve the formulated result, a complex combination of the principles of a wide range of scientific fields is necessary – commodity science, nutritionology, in particular dietetics, medicine, food technology, gerontology, marketing.

The conducted research is aimed at the analysis of the main theoretical and applied aspects of the development of products for enteral nutrition of representatives of older age groups in emergency situations, the determination of the most promising raw materials for the production of these products.

The presented data reveal prospects for stimulating the production of both ingredients and products for enteral nutrition as a whole at domestic levels, developing their assortment and solving the problem of import dependence by drawing the attention of state bodies to solving conceptually important issues for ensuring the health of the population.

1.1 GENERAL APPROACHES TO ENSURING THE NUTRITIONAL NEEDS OF PERSONS BELONGING TO OLDER AGE GROUPS

According to generally accepted scientific principles, the physiological aging of the human body is defined as a systemic, hereditarily programmed natural phenomenon, during which there is a gradual degeneration and loss of basic functions, in particular, the ability to active regeneration [7, 8].

It is generally accepted that a person's physiological old age occurs when practically healthy people reach the elderly (60–74 years), senile (75–90 years), life period of long-lived people (90 years and older) [6, 7]. It is a scientifically proven fact that the process of physiological aging, uncomplicated by certain diseases, lesions and/or pathological processes, is characterized by a gradual slowing down of the intensity of metabolic processes, which determines the vital activity of the human body. It is worth noting that self-renewal of proteins, utilization of glucose, use of oxygen by cells and release of carbon dioxide, use of enzymes by tissues of the heart, liver, and kidneys are reduced in the body. Also, lipid complexes and components are observed in organs and tissues [7, 8]. Based on the analysis of scientific information [7, 9], a correlational interdependence between the aging of the human body and the reduction of its adaptive capabilities, functionality of systems and organs was established. mechanisms of biochemical and enzymatic activity.

One of the main needs of a person, the satisfaction of which directly determines the level of life and quality of life, is the need to provide adequate and complete nutrition.

It is generally accepted that food is considered not only a substrate that performs plastic and energy functions, but also a complex biologically active factor of immune, bioregulatory, rehabilitation, motivational and signaling influence on the life support of the organism. Based on this statement, to ensure proper nutritional support of representatives of older age groups, specialists in the field of herodietics formulated the following basic principles of nutrition for the specified category of persons [7, 10, 11]:

– balanced energy value of the food ration in accordance with the actual energy expenditure of the person;

– the maximum possible variety of ingredients presented in the diet, which will contribute to ensuring the balance of all indispensable metabolic components;

– easy digestibility and digestibility;

– the presence of substances that will provide moderate stimulation of the digestion process and ensure the activity of enzyme systems;

– reasonable distribution of the nutritional value of food components between individual meals;

– food should be fractional, i.e. 4–5 times a day. The last meal should be consumed 2.5–3 hours before bedtime;

– the use in food of products and dishes that are characterized by a rather light enzymatic action;

– cooking technologies for the elderly must be gentle (easy to digest based on the ingredient composition);

– full supply of the body with a sufficient amount of drinking water for its necessary hydration, especially in the hot season;

– antisclerotic focus of the diet, which should be provided through the use and presence of sources of antisclerotic substances;

– maximum individualization of diets based on the specifics of metabolism, the state of individual physiological systems, organs and tissues of representatives of older age groups.

Based on the results of the analysis of sources [7, 11, 12], it was investigated that the results of aging processes are most significantly reflected in the digestive system of older people. Thus, as a result of the gradual processes of atrophy of the intestinal mucosa, in particular its destruction and decrease in the activity of glandular cells, there is a deterioration of its motility, a decrease in the level of secretion, the acidity of gastric juice, and the concentration of enzymatic substances. These disturbances, in turn, cause deterioration of the work of the gastrointestinal tract, the digestion process, the development of the initiators and pathogens of putrefactive processes in the intestine, and an increase in the need for pre- and probiotics [7, 11].

It was analyzed that the prevalence of gastrointestinal dysfunctions in people belonging to this group is associated with disorders of the membrane digestion process [13]. Based on this, it was investigated that the increase in the level of membrane hydrolytic splitting almost proportionally depends on the decrease in the level of entero-gastric digestion. This, in turn, allows to state that in the process of age-related changes in the human body, the rate of starch assimilation when consuming food products that contain it in moderate amounts practically does not change.

Based on scientifically proven data [7–9], the actual decrease in the level of basic metabolism in people belonging to older age groups was analyzed. This is due, first of all, to the physiological processes of aging, as well as, in most cases, low physical activity of the representatives of these persons. Considering this, the energy value of the daily rations of elderly, elderly and senile people should be moderately limited.

The analysis of the results of the studies of many scientists and researchers [7, 8, 14, 15] allows to state that the average level of energy metabolism, and accordingly energy needs, decreases with aging. In particular, it decreases by 16–20 % in the elderly, and by 30 % in the elderly, relative to this indicator of people aged 18–35. Depending on body weight, age and level of physical activity in men aged 61–74, it is on average 1800–2100 kcal/day, for women – 1600–2000 kcal/day. After reaching the age of 75 in men, this indicator is on average 1600–1900 kcal/day, in women – 1400–1700 kcal/day [7, 10, 12, 16].

It is worth noting that in many cases, excessive consumption of food products by representatives of older age groups can be dangerous due to the risk of obesity, the appearance of many diseases. In particular, they are varicose veins, type II diabetes, atherosclerosis, gallstone and urolithiasis, coronary disease heart attack, stroke, and others [7, 9, 10]. The frequency and severity of the course of these diseases increases with age. In this regard, one of the key requirements is a gradual decrease in the energy value of the daily rations of people who belong to the older age categories, as the body ages. Taking this into account, to reduce the energy value of food rations of people who belong to the elderly, elderly and long-lived people, it is recommended to reduce the content of lipid and carbohydrate components of food [8, 10, 14, 16].

In order to systematize scientific approaches to meeting the needs of people belonging to older age groups, the results of research into the main energy substrates were analyzed [7–10, 16]. It has been studied that the optimal ratio between macronutrients (%) for representatives of older age groups with normal metabolism from a scientific point of view is proteins : lipids : carbohydrates –

16–20 : 25–30 : 55–59. Quantitative norms of the main energy substrates presented in **Table 1.1** are recommended for consumption by representatives of older age groups. In addition, elderly people who lead a sedentary lifestyle are recommended to limit the consumption of carbohydrates.

● **Table 1.1** Recommended rates of consumption of macronutrients by representatives of older age groups with normal metabolism

Age and gender groups	Recommended consumption rates, g/day		
	proteins	lipids	carbohydrates
60–74 years			
men	72–105	50–70	240–310
women	64–100	44–67	220–295
74–90 years			
men	64–72	44–50	220–240
women	56–68	39–57	193–112

Recommendations regarding the composition of the main macronutrients deserve special attention in the analysis and systematization of data on ensuring the nutritional needs of the elderly, senile and long-lived people with normal metabolism [7, 10, 12, 16]. In particular, in addition to ensuring compliance with the amino acid score of food rations in accordance with the recommendations of FAO/WHO specialists, it is also necessary to ensure the share of essential amino acids within at least 40 % of the total amount of protein [7, 8, 10, 15]. Taking into account the need to ensure the proper level of digestibility, it is more appropriate to represent the protein component of rations at the expense of dairy, egg and fish products.

The analysis and systematization of scientific data on the lipid component of rations for herodietic purposes [7, 10, 16] allow to state that the optimal ratio of vegetable and animal fats is 1:2, omega-3 and omega-6 fatty acids – 4:1. It is also necessary note that the optimal amount of dietary fiber consumption in the daily diet should be about 30–40 g [14, 16].

Vitamins and mineral elements, and especially those characterized by antioxidant properties, play an important role in maintaining the physiological processes of people of older age groups. According to the results of the analysis and generalization of scientific literature and experimental data [6–8, 10, 15–17], it was established that the optimal daily intake of vitamins for the elderly, senile and long-lived people is indicated in **Tables 1.2** and **1.3**.

Based on the analyzed scientific information on the consumption of nutrients, approaches to ensuring the nutritional needs of people of older age groups, the recommended consumption rates of the main nutrients were studied. It has been established that it is recommended for older people to consume dairy products, seafood, fish, eggs, oils, poultry, vegetables, fruits, berries, seeds, nuts, whole grain products, and biologically active supplements. One of the options for enriching the diets of people of older age groups is the consumption of special food products of increased nutritional, in particular, biological value, which will take into account the herodietic features of the metabolic process.

● **Table 1.2** Recommended rates of consumption of basic vitamins by representatives of older age groups with normal metabolism

Vitamins	Unit of measurement	Men	Women
Ascorbic acid	mg	90–120	90–110
Retinol		0.9–1.1	0.9–1.1
Tocopherol		15–25	15–20
Thiamine		1.6–1.7	1.5–1.6
Riboflavin		1.7–2.2	1.6–2.0
Niacin		1.5–2.0	1.5–1.8
Pantothenic acid		5.0	5.0
Pyridoxine		2.5–3.5	2.5–3.5
Cyanocobalamin	μg	3.0	3.0
Biotin		45–50	43–45
Folic acid		250–400	250–400
Calciferol		7–15	5–12
Phylloquinone		100–120	90–110

● **Table 1.3** Recommended rates of consumption of the main mineral elements by representatives of older age groups with normal metabolism

Mineral elements	Unit of measurement	Men	Women
Potassium	mg	2200–2500	2200–2500
Sodium		1200–1400	1200–1400
Calcium		900–1200	800–1100
Phosphorus		900–1200	800–1100
Magnesium		450–600	400–550
Ferum		12–18	10–16
Zinc		12–15	12–15
Fluorine		2–4	2–4
Manganese		2	2
Kuprum		1	1
Iodine	μg	120–150	110–140
Molybdenum		60–70	60–70
Selenium		60–70	55–65
Chrome		50	50

1.2 THE CONCEPT OF PROVIDING NUTRITIONAL NEEDS OF REPRESENTATIVES OF OLDER AGE GROUPS IN EMERGENCY SITUATIONS

It is generally accepted that a balanced and rational diet is the basis of any person's life. Its completeness and compliance with the specificity of metabolic processes are especially important for people with somatic diseases and injuries during treatment and rehabilitation periods, in particular, representatives of older age groups. Optimum nutritional status largely determines the ability of victims to better tolerate illness and critical conditions, overcome them with less loss of health and fuller and faster rehabilitation.

It has been established that in emergency situations, in particular diseases and injuries, as a result of stress and physiological changes that occur during the inflammatory process, metabolic metabolism accelerates. This process of a complex metabolic response of the human body to a generalized inflammatory reaction, accompanied by increased energy needs and a decrease in the ability to utilize endogenous substrates, received the scientific definition of "hypermetabolism-hypercatabolism syndrome" [18–20].

As a result of the action of any etiological factor, it is recommended to carry out nutritional support, which is defined as the process of providing the body with optimal nutrition using special products, methods different from the usual eating [12, 21, 22]. In particular, this factor can be increased mental and physical stress, in particular emotional stress, mechanical injuries of tissues and organs, blood loss, sepsis, polytrauma, inflammatory process of various degrees of severity, thermal injuries, etc. The development of products that will provide nutritional support is based on modern scientific research on the balance of the nutrient composition and its compliance with the needs of people in emergency situations. In particular, the use of such specially modeled and directed products is considered particularly relevant for nutritional support of persons belonging to older age groups.

Numerous studies in the field of providing nutritional needs of representatives of older age groups in emergency situations [7, 12, 14, 15, 20, 22] make it possible to investigate and reveal the specifics of physiological processes. Also, they, in turn, are the basis for the development of the basic principles of their nutrition for this category of persons in the specified condition.

The scientific basis for the development of modern principles of human nutrition in emergency situations, in particular under the influence of stress caused by nervous and physical overloads, diseases, and injuries, are the fundamental provisions on the specificity of the resulting metabolic needs of the body [23–25]. Particular attention should be paid to the fact that, in emergency situations, compliance with the fundamental principles of the theories of balanced and adequate nutrition is of primary importance in ensuring the nutrition of people, particularly the elderly.

According to this concept, developed on the basis of the concepts of differentiated, directed (targeted) and individual provision of nutrients, the needs of victims for the recovery of the body depend to a large extent on many factors. First of all, they are the type and severity of damage to the body due to stress and physical injuries and diseases, body constitution, age, gender, energy

expenditure, level of neuropsychological stress, etc. [23, 26, 27]. This, in turn, determines the need for a detailed analysis of the peculiarities of physiological processes and states of people, which were caused as a result of the psycho-emotional and physical impact of emergency situations.

The basic scientific basis for this was the theory of metabolic reactions developed by the Scottish scientist D. Cuthbertson, caused by various influencing factors [23, 27, 28]. This theory is based on 2 phases of the body's metabolic response to the transferred loads and damage identified by the researcher:

– decline in metabolic activity (EBB) – observed during the first 12–24 hours. This phase is characterized by a short-term decrease in the activity of physiological processes, the transfer of oxygen to the affected areas of the human body, the synthesis of energy necessary to support the metabolism of the human body at rest;

– increase in metabolic activity (FLOW) – occurs after the end of the decline during the next 5–7 days. This phase is characterized by an increase in the activity of physiological metabolic processes, in particular, an acceleration of catabolism (especially active in peripheral affected tissues and organs) and anabolism (as a result of which acute-phase proteins are produced in the body) [23, 26, 27].

In turn, the analyzed theory was refined and improved by the American clinician F. D. Moore. Scientists have proven and substantiated that the cause of the decay of affected cells and tissues, as a result of the loss of the victim's body weight, is primarily the lack of nutrients for the restoration of the affected areas [27, 29, 30].

As a result of a significant physical injury, the victims have a sharp violation of the water balance, which, in turn, is associated with a significant loss of intercellular fluid, a change in its pressure; tissue hyperventilation; hyperdynamic mode of blood circulation. Because of this, during the EVV phase, the stabilization of the hydrobalance becomes important, which causes in the first 12–24 hours. the need to provide the body with an adequate amount of liquid, Na^+ and Cl^- electrolytes, vitamins and mineral elements [27, 29]. In particular, according to the recommendations developed by specialists in the field of nutritional support [18], meeting the increased needs for certain vitamins and mineral elements is mandatory during this phase. In particular, such vitamins are fat-soluble retinol, tocopherol and water-soluble ascorbic acid, thiamine, riboflavin, pyridoxine, cyanocobalamin, folic acid; mineral elements Magnesium and Zinc. This, in turn, is explained both by the ability of these nutrients to act on the nervous system, somewhat suppressing active excitement, and by their antioxidant properties.

It has been established that the primary reaction of the body to the action of any etiological factor is stress, which also affects the body of representatives of older age groups under the influence of emergency factors. Under the influence of this factor, substrates are mobilized, which can quickly release a significant amount of energy when split under the condition of a reduced level or complete absence of oxygen [24, 25]. Thus, under these conditions, carbohydrates become the main source of energy for the body. At the same time, the body's carbohydrate reserve is quite limited, which leads to its rather rapid exhaustion and the need to find new resources (**Table 1.4**) [24, 25, 31].

Table 1.4 Carbohydrate reserves in the body of a person with an average body weight of 74 kg

Body substrate	Mass of the substrate, kg	Potential energy value, kcal
Muscle glycogen	0.5	2000
Liver glycogen	0.2	800
Glucose (extracellular fluid)	0.02	80

It has been studied and established that as a result of the physiological effect of stress, the speed of glycogen breakdown and consumption by the affected parts of the body increases approximately 4 times [24, 31, 32]. Scientists have also researched that with the beginning of the FLOW phase, glycogen reserves in the body are depleted in approximately 2–6 hours. Because of this, the process of gluconeogenesis is activated in the body, which is defined as the process of glucose formation from other available energy substrates: lipids, amino acids of skeletal muscles (especially glutamine and arginine), glycerol, and triglycerides [25, 32].

It has also been scientifically established that a feature of the FLOW phase is an increase in the level of adrenocorticotropic hormone, adrenaline and norepinephrine in the blood of the affected person. Their high concentration, in turn, increases the consumption of glucose by the body, causes the beginning of proteolysis and lipolysis, which ultimately causes the occurrence of negative protein and lipid balances, and, as a result, nutritional deficiency [25, 31, 32]. In modern scientific and special literature [1], this term is defined as a state of the body characterized by a deficiency and/or imbalance of macro- and micronutrients, causing functional and morphological disorders and/or homeostasis disturbances. In order to minimize the negative effect and eliminate these metabolic disorders, to normalize the state of the body, products for nutritional support of a person are actively used in modern practice.

In order to ensure the optimal energy balance of the body of persons affected by emergency situations, it is recommended to start nutritional support with the appropriate amount of macro- and micronutrients immediately after the onset of the FLOW phase [25, 27–29, 31].

According to the formulation developed by specialists of the American Society of Parenteral and Enteral Nutrition (ASPEN) [33], nutritional support is defined as the process of providing the body with optimal complete nutrition through the use of certain products and a number of methods different from the usual eating. It, in turn, includes additional food fortification, partial and/or full enteral (in the form of oral administration and/or tube administration) or parenteral nutrition [27–30] (**Fig. 1.1**). It is also appropriate to note that in certain cases they are combined. At the same time, the consumption (use) of special food products is considered to be the optimal way to meet the needs of the injured person in these conditions.

Food fortification of the diet involves the necessary additional enrichment of the diet due to the protein component, micronutrients, biologically active substances or their complexes. Such additional food components can be consumed both separately and when added to certain dishes and products, including in the process of their manufacture and preparation [31, 33].

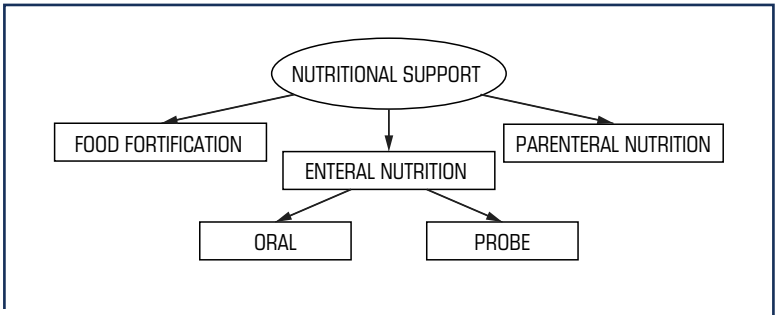

Fig. 1.1 Methods of nutritional support

Enteral nutrition involves ensuring the nutritional needs of the body in nutrients due to the consumption (use) of specially developed products orally and/or through a nasogastric tube in severe conditions of the victims. This method of nutritional support allows to provide the energy and plastic needs of the body while preserving the functions of the gastrointestinal tract [21, 29, 33].

Parenteral nutrition involves the introduction of the necessary nutritional mixtures of nutrients or individual nutrients without contact with the gastrointestinal tract directly into the blood through the main vessels and peripheral veins. Modern international experience in the treatment of patients with a high degree of severity of lesions, injuries and diseases indicates the need to use products for parenteral nutrition almost immediately after the elimination of acute disorders. In particular, these can be dysfunctions of hemodynamics and respiratory functions, and the use of this method is largely due to the need for rapid restoration of energy and plastic resources of the affected body [28, 29, 31, 33].

Based on the results of the given information, it can be summarized that in emergency situations, enteral and parenteral nutritional support become especially relevant. It is also worth stating that for people in severe critical conditions, the enteral method is considered the most physiologically successful compared to the parenteral method, which is due to the following factors:

– ensuring the supply of the necessary nutrients through its oral and tube administration (introduction) makes atrophy of the mucous membrane of the gastrointestinal tract impossible;

– the risk of infectious complications and the development of multiple organ failure syndrome is reduced;

– it is possible to reduce the severity of the stress reaction;

– the possibility of protein synthesis and regulation of metabolism in internal organs, especially in the liver, is assumed;

– more favorable conditions are created for the implementation of biochemical processes that occur in the walls of the intestine, which is impossible with parenteral administration of nutrients;

– there is no need to observe sterile conditions;

– lower level of necessary economic costs [19, 23, 27, 31].

According to world practice, an integral part of the nutritional support of victims in emergency situations is the provision of specialized nutrition, developed in accordance with the specifics of the body's metabolic processes. Thus, it is scientifically established that there is a direct correlation between the severity of the course of the disease and the trophic supply of the victims: the lower the nutrient deficiency, the less often multiple organ failure and complications are observed [29, 31, 33].

Based on the above, it was analyzed that in most cases the most successful and convenient method of providing nutritional support is enteral nutrition (both oral and tube feeding). This is due to the fact that in critical conditions, the gastrointestinal tract is a potentially dangerous source of endogenous infection, and the presence of a food substrate in it prevents the appearance of dystrophy and atrophy of the mucous membrane, disruption of its barrier functions [27, 29]. Additional advantages of enteral nutrition in comparison with parenteral nutrition are simpler requirements for the sterility of the conditions of preparation and use (introduction), a much smaller number of side effects, and a cheaper cost (by 3–6 times) [27, 29, 32].

In the case of insufficient provision of the victim's organism with energetic and plastic substrates, first of all, there is a failure of their mass transfer to areas and cells of the body [26, 34]. In order to restore and properly function the body of a person affected by emergency situations, it is of great importance to observe the principle of balance in the diet of the main macronutrients. Most specialists in the field of clinical dietetics and the development of special products for nutritional support of the elderly recommend the following norms of the optimal ratio of the total energy value between the main macronutrients, %: proteins : fats : carbohydrates – 20–25 : 25–32 : 43–55 [7, 11, 18, 19, 34].

Carbohydrates are the main metabolic substrate for people, particularly the elderly, in emergency situations, including physical illnesses and injuries. Their splitting can occur with the release of energy, including in the absence of oxygen, which is defined as glycolysis. In conditions of partial or complete impossibility of mitochondrial respiration of cells, these macronutrients can be absorbed in damaged areas of the body [24, 25, 29]. The minimum physiological need necessary to meet the basic metabolic needs of persons of older age groups in the studied conditions in carbohydrates is considered to be 200 g/day, the optimal amount is 320–390 g/day [27, 29, 31, 34]. The optimal carbohydrate substrate for meeting the needs of the injured, including the elderly, is glucose, which is the initial energy substrate for glycolysis. Under these conditions, the maximum rate of utilization of glucose with exogenous administration is considered to be within the range of 0.5–0.7 g/kg/day [27, 29, 34]. At the same time, it was established that the digestibility of glucose under these conditions depends, first of all, on the adequacy of blood flow and the ability of cells to utilize it [25, 27, 29]. At the same time, it has been investigated that the excess supply of carbohydrates to the body of the affected person is characterized by an increase in resistance to endogenous insulin [23, 25, 26].

As a result of disruption of normal physiological metabolism and redistribution of proteins in the body of the affected persons, special importance is attached to protein metabolism in the diet of the affected persons.

Under these conditions, the basic indicator of this metabolic process is the nitrogen balance, which is the difference in the amount of nitrogen that enters the body with proteins, amino acids, and that is removed from it in various ways [26, 29, 34]. At the same time, it should be noted that nitrogen losses indicate a loss of protein in the body and lead to a decrease in body weight (1 g of nitrogen corresponds to 6.25 g of protein or 25 g of muscle mass) [30–32].

When researching the protein needs of older people who have suffered from emergency situations, it is appropriate to note the presence of somewhat different approaches among certain scientists. In particular, on the basis of some studies, it was established that the protein needs of victims of somatic lesions are in the range of 1.5–2.0 g/kg/day, at the same time, there is a statement according to which protein should enter the body of victims in the amount of 2.5–2.8 g/kg/day [29, 32].

At the same time, the exact determination of protein substrate needs is individual for each victim in accordance with the specifics of the injuries received and requires the implementation of individual nitrogen balance studies [28, 29, 32, 34]. The fact that in the diet of persons affected by emergency situations, including people of older age categories, the ratio of the number of calories from the non-protein component to nitrogen should be 90–110:1 [27, 29, 33, 34]. For persons with a total area of somatic lesions of more than 30 % – 80–90:1 [31, 34].

When analyzing protein needs, it should be noted that the amino acid L-glutamine acquires special importance in meeting the nutritional needs of people with somatic diseases and injuries. It has been studied that due to the generalized inflammatory process occurring in the body due to the effects of emergency factors (sepsis, blood loss, injuries), the consumption of this amino acid increases significantly (almost by 65–75 %) [25, 29, 31]. This fact is due to the fact that the amino acid L-glutamine becomes indispensable for the restoration of somatic parts of the body in case of injuries and injuries due to emergency situations. It should be noted that this nutrient becomes the basic substrate for the gastrointestinal tract due to the possibility of utilization by enterocytes and colonocytes to a greater extent than glucose). Also, its consumption reduces the possible level of purulent complications, increases the level of protein utilization by muscles and the general tone of blood vessels by reducing their permeability and promoting the restoration of structural integrity, stimulates the synthesis of hormonal drugs necessary for recovery and has pronounced antioxidant properties [32, 34].

Due to their high energy value (9.3 kcal/g), when meeting the needs of people in emergency situations, lipids are of particular importance and are considered the most beneficial source of energy [27–29, 31]. It has been studied that one of the main processes occurring in the human body as a result of emergency factors is lipolysis, as a result of which fatty acids and glycerol are formed from these macronutrients [28, 29, 31]. Fatty acids become the most important energy source for muscles and the liver, and also contribute to the acceleration of neutralization of microbial harmful cells by the liver [26, 28, 29]. It is appropriate to note that glycerol under these conditions becomes one of the basic substrates for gluconeogenesis [27, 29]. Based on the recommendations of experts in the field of nutritional support in emergency situations [26, 29, 31, 34], the needs

of the body in the studied conditions in lipids are within the range of 0.7–1.2 g/kg/day, depending on the severity of the lesion.

It is generally accepted that one of the best ways to adequately provide the affected person with fatty acids is to use omega-3 and omega-6 polyunsaturated fatty acid complexes in their diet. The use and combination of these substances, which make it possible to provide the body not only with a source of energy, but also make it possible to timely and effectively regulate inflammatory processes in injured parts of the body [27, 30]. Due to the properties of interacting with transmembrane signaling molecules, these fatty acids have properties to reduce the level of inflammatory processes. In addition, they are able to inhibit the uncontrolled release of active leukocytes, stimulate the body's defenses by restoring the cell membranes of the affected areas of the body, and normalize the functioning of the endocrine and nervous systems [27, 28].

It is also appropriate to note that dietary fiber plays an important role in the diet of the nutritional needs of older people who have been negatively affected by emergency situations. The use of these nutrients in nutritional support is due to their ability to favorably affect the gastrointestinal tract due to the absorption of bile acids, cholesterol, and promote the increase of intestinal motility [26, 27]. In this regard, it is considered expedient and favorable to ensure the presence of non-starch polysaccharides, fructo-oligosaccharides, pectin and lignin in the nutrition of this group of affected people [12, 21, 32]. 15–25 g/day is considered the most recommended daily intake for people of older age groups, in particular in the state of damage due to emergency situations [6].

It should also be noted that quite a lot of attention is paid to vitamin therapy when providing the nutritional needs of representatives of older age groups in emergency situations. In particular, specialized specialists of the international organizations ESPEN (European Society of Parenteral and Enteral Nutrition) and ASPEN (American Society of Parenteral and Enteral Nutrition) have developed recommendations on optimal norms for meeting the needs of the studied category of persons in the mentioned states [31, 33, 34]. In particular, according to them, optimal provision of needs for retinol, thiamin, riboflavin, niacin, pyridoxine, cyanocobalamin, ascorbic acid, calciferol, tocopherol, phylloquinone becomes especially important (**Table 1.5**).

In the process of conducting research by many specialists in the field of nutritional support of people, especially the elderly, in emergency situations, it was investigated [14, 15, 19, 23] and it was established that providing an adequate amount of vitamins is important. In particular, the level of satisfaction of vitamin needs determines the nature of optimization of protein, carbohydrate, and lipid exchanges, reduction of the activity of pain syndrome, free radical oxidation process in tissues and organs, increase of the level of tissue respiration. Ensuring the proper exchange of thiamine, riboflavin, pyridoxine, and tocopherol is especially important.

It is also appropriate to note that ascorbic acid plays a rather important role among vitamins, the metabolic exchange of which is in a complex relationship with protein exchange. Thus, the results of scientific research [30] show that an increased amount of ascorbic acid (from 50 to 200 mg) helps to optimize the protein status of the body. This, in turn, is caused by the fact that

tissue regeneration of dehydroascorbic acid into ascorbic acid is disrupted with significant protein losses. The latter, being a fairly effective natural antioxidant, takes an active part in the body's redox reactions, forming a hydrogen atom transport system with dihydroascorbic acid. During this process, a complex of enzymes is activated, the valency of some metals changes (in particular, $Cu^{2+} \rightarrow Cu^{+}$). It is worth noting that thanks to this, ascorbic acid is characterized by an effective stimulating effect on recovery, promotes the activation of the endocrine glands, facilitates the process of converting ferrum into ferrite [27, 28].

● **Table 1.5** Recommended norms of daily consumption of individual vitamins by representatives of older age in emergency situations

Vitamins	Unit of measurement	Recommended usage rates	
		Minimal	Maximum
Retinol (A)	μg	1000	3500
Thiamin (B1)	mg	1.8	3.0
Riboflavin (B2)	mg	2.5	6.0
Niacin (B3)	mg	1.5	5.0
Pyridoxine (B6)	mg	2.5	6.5
Cyanocobalamin (B12)	μg	3.0	9.0
Ascorbic acid (C)	mg	90	250
Calciferol (D3)	μg	10	35
Tocopherol (E)	mg	15	60
Phylloquinone (K)	μg	120	400

An important factor that determines the success of the process of treatment and rehabilitation of injured persons, including the elderly, is the satisfaction of needs in mineral elements. Based on this, according to the recommendations of specialists [21, 23, 27, 31, 33], it is quite important to increase the level of meeting the needs of trace elements (**Table 1.6**), in particular Ferrum, Manganese, Cuprum, Zinc, Selenium, Chromium, Molybdenum, Iodine.

Thus, on the basis of the given information, it is possible to summarize the rather important role of proper supply of mineral elements in the process of treatment and rehabilitation, including representatives of older age, from adverse emergency situations.

In the course of the conducted analytical research, it was also established that many scientists [22, 23, 26, 28, 32, 33] noted the importance of using a rationally planned strategy of saturating the body of victims with liquid. This, in turn, makes it possible to improve the thermoregulatory ability of the body, to improve the level of pressure in the body. It has been studied that the optimal amount of fluid intake enriched with electrolytes Na^{+}, K^{+} and glucose for the studied

group of people is within 1.5–2.5 l/day [28, 30, 32]. It has been established that the use of liquid mixtures saturated with all necessary macro- and micronutrients is the best way to ensure proper nutritional support.

● **Table 1.6** Recommended norms of daily consumption of certain trace elements by representatives of older age in emergency situations, μg

Microelement	Unit of measurement	Recommended limits of norms of use	
		Minimal	Maximum
Ferrum	mg	12	30
Zinc	mg	12	25
Cuprum	mg	1.5	5.0
Manganese	mg	2	5
Iodine	mg	0.15	0.50
Molybdenum	μg	70	120
Selenium	μg	70	130
Chrome	μg	50	100

1.3 FEATURES OF ENSURING THE NUTRITIONAL NEEDS OF REPRESENTATIVES OF OLDER AGE GROUPS SUFFERING FROM DIABETES IN EMERGENCY SITUATIONS

Diabetes mellitus is considered one of the most common diseases in our time. In particular, this fact is confirmed by the information that almost 415 million people around the world suffer from this disease, and the share of these people in different countries ranges from 4 to 7 % of the total population [34, 35]. There is information that this disease has a constant tendency to increase, showing a special increase in economically developed countries after 65, and in developing countries – between 45–64 years [34, 35]. These data confirm the wide prevalence of this disease among people who belong to older age groups, especially with regard to type II diabetes. It is worth noting that this type of disease is characterized by the fact that the patient's body does not produce the required amount of insulin or does not use it to the full extent [35].

It is worth noting that diabetes is a very common disease among people belonging to older age groups. In particular, it was established that, according to statistical data, more than 25 % of these representatives suffer from the specified disease, about 50 % have prediabetes [35]. It was also studied that representatives of older age groups suffering from diabetes are characterized by a higher level of other diseases, in particular, stroke, hypertension, and somatic lesions [35]. Based on the above information, it is relevant to study the specifics of ensuring the nutritional needs of older people suffering from diabetes, particularly type II.

The fact that diabetes is widespread in modern society, the development of which is caused by a significant level of stress, deserves increased attention [34, 35]. This phenomenon is especially relevant for the population of Ukraine, which is characterized by increased psycho-emotional stress due to the military attack of the russian federation, its missile strikes. It is worth noting that during stress, human glands produce an increased amount of adrenaline, norepinephrine, and cortisol hormones. The latter in a normal concentration contributes to the healing of wounds, regulation of the immune system, maintenance of normal blood pressure, however, with prolonged release, it increases the level of glucose, increasing the level of sugar in the blood [36]. As a result, the level of development of type II diabetes mellitus increases in the affected person's body.

It is appropriate to note that a mandatory condition for the treatment and rehabilitation of persons belonging to the older age categories, exposed to emergency situations and additionally suffering from diabetes, is the rational provision of the food ration. This is caused primarily by the fact that the most significant fluctuations in the level of sugar in the blood occur after eating [34, 35]. Full satisfaction of the energy and plastic needs of this category of victims, taking into account the need to normalize glucose homeostasis, is possible only under the condition of maximum compliance with modern principles of clinical diabetology.

Modern scientific data [7, 12, 33, 36] indicate that the problem of providing the necessary macro- and micronutrients to people suffering from diabetes requires a special approach to this process. Thus, the following principles for their diet therapy were developed by scientists who are specialists in the field of nutritional support for this category of people [7, 12, 31, 33, 36]:

– ensuring the ratio in the total energy value of food, %: proteins : lipids : carbohydrates – 30 and less : 27–35 : 40 and more. The increased content of proteins and lipids in the diet is due to the process of gluconeogenesis in emergency situations and the critical functioning of the Corey cycle. It was established that as a result of these processes under the influence of a stress factor, glucose synthesis occurs from these substrates;

– ensuring preference in favor of vegetable oils in the lipid component, as they contain mainly polyunsaturated fatty acids;

– the inclusion of carbohydrates in the diet should be based on scientifically based data, based on information about their glycemic index, the degree of digestibility and refinement, the recommended daily rate of their consumption, their share in the total diet;

– ensuring the presence of dietary fibers in the diet, which will slow down the increase in motility of the stomach, its emptying and shorten the period of movement of nutritional substrates through the intestine and, as a result, will prevent sharp fluctuations in the blood sugar level of the affected person;

– stability of the regime of nutritional support – obtaining nutritional substrates should involve 5–6 receptions (administrations) per day with a clearly defined isocaloric distribution of energy value.

Thus, on the basis of the analyzed and researched material, it can be concluded that one of the conditions for the successful treatment and rehabilitation of representatives of the older age groups suffering from diabetes in emergency situations is a complete diet developed on the

basis of scientifically based data on the specifics of physiological processes their body. Adequate provision of the nutritional needs of this category of people should be ensured taking into account the peculiarities of their physiological needs and increased sensitivity to the carbohydrate component of the diet.

1.4 CHARACTERISTICS OF THE MAIN TYPES OF RAW MATERIALS THAT CAN BE USED IN THE PRODUCTION OF PRODUCTS FOR ENTERAL NUTRITION

The modern dynamic rates of scientific research in the field of nutrition and medicine, supported by the rapid development of production capabilities, cause the spread of the practice of producing special products for nutritional support of a targeted effect on the human body [29, 32]. This determines the need to find and use high-quality raw materials for production, which will meet the ever-growing demands of consumers, in particular representatives of the older age group, regarding the nutritional and biological value of ready-made products.

The main requirements for raw materials for the production of products for nutritional support are: the presence of documents confirming safety, proper quality, registration by the relevant executive authority, a high degree of purification, dispersion, solubility in solutions. For physiologically active components, additional requirements are set for the availability of information on the confirmed effectiveness of the action [28, 29, 32, 34]. It should also be noted that the cost of raw materials in the production of this type of product is the main factor that determines its cost price and determines the need for the development of the raw material base [29, 34].

In the practice of production of products for nutritional support of persons belonging to older age groups in emergency situations, in particular with the additional disease of type II diabetes, basic and additional raw materials are used. The main raw materials used are: purified and prepared water; glucose, fructose, sweeteners; omega-3, omega-6, omega-9 polyunsaturated fatty acids, vegetable oils and extracts; proteins, peptides, amino acids and their concentrates. To increase the biological value of this type of product, food fibers, vitamins and minerals, as well as food premixes containing them, are added [7, 14, 16, 29, 33].

The main raw material used in the production of products for the nutritional support of the human body are carbohydrates. Among them, glucose is the most common [7, 28, 29]. This is explained by the fact that it is one of the main energy substrates during the stress reaction. Since glucose can be broken down with the release of energy in the absence of oxygen (glycolysis), it is absorbed by organs and tissues for which mitochondrial respiration is partially or completely unavailable. These include tissues in the areas of lesions, when lipids cannot be a source of nutrition due to impaired blood circulation [28, 31]. Thus, glucose is the only energy substrate that provides nutrition for cells and tissue for their recovery. In addition, this carbohydrate enhances redox processes, improves the antitoxic function of the liver, stimulates the contractility of the myocardium, and prevents excess water loss by the body. At the same time, it should be noted that

the digestibility of glucose in a critical state depends on the adequacy of perfusion (blood flow), the ability to utilize it by cells (insulin resistance) [23, 27, 29].

Another component of the carbohydrate group that is quite actively used in the production of special products for nutritional support is fructose. It is absorbed by the body after being converted into glucose, which is why it is a timely source of energy. In addition, fructose is not absorbed by insulin-dependent tissues, stabilizes the blood sugar level, which determines the possibility of its use in products for nutritional support of the body of people suffering from diabetes [27, 34, 35]. Research by a number of scientists [31, 36] has proven that when using fructose in products for enteral nutrition of victims in an emergency, particularly critical condition, an increase in the ability of cells to stimulate the immune system is observed. In particular, fructose promotes the release of substrates that inhibit the action of infectious agents.

One of the sugar substitutes that is widely used as a raw material in the manufacture of products for the nutritional support of people suffering from diabetes is sorbitol [34–36]. This component practically does not lead to an increase in the level of sugar in the blood, being slowly absorbed from the gastrointestinal tract [34]. The recommended dose of its daily use is up to 45–50 g/day. There are scientific data [34, 35] that sorbitol is characterized by a detoxifying effect.

Protein components deserve special attention when analyzing raw materials for the production of products for enteral nutrition. A mandatory condition for the protein component of these products is the content of all essential amino acids [27, 29, 31]. Protein concentrates (of both animal and vegetable origin), isolates, peptides, amino acids and their mixtures are used to meet protein needs [27, 29, 31–33]. The main purpose of their use is to ensure the rapid recovery of protein losses under the influence of gluconeogenesis and to create favorable conditions for the metabolic processes of the body's energy and plastic exchange. It should be noted that the main criteria for the selection of raw materials for providing the protein component of products for nutritional support are its biological value, high solubility, and the ability to stabilize dispersed systems [29, 31, 32]. Considering this, in the production of products for the nutritional support of people with somatic diseases and injuries, it is advisable to use whey protein concentrates characterized by a high content of protein, vitamins (retinol, ascorbic acid, thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, cyanocobalamin), minerals elements (calcium, sodium, potassium and others). In particular, the ratio of calcium/phosphorus and calcium/magnesium is close to optimal (1:2 and 1:7, respectively), which indicates high assimilation by the body [32].

Amino acids require special attention when characterizing the raw materials used in the production of products for enteral nutrition. The value of their use is due to the simplified process of assimilation and the possibility to balance the amino acid composition according to the specific needs of the body [6, 15, 23, 32]. Studies conducted by clinical nutritionists [23, 32] show that due to generalized inflammation, the content of glutamine in the blood decreases by 50–60 % and remains at a reduced level for a significant period of time (up to 30 days). Due to the fact that the stress reaction is accompanied by a significant increase in its consumption, in emergency situations,

in particular critical conditions, glutamine is considered an irreplaceable amino acid [25, 27, 32]. In addition, it is necessary for the restoration of damaged areas of the body, has an anti-inflammatory effect, increases the tone of blood vessels, contributes to the restoration of the structural integrity and activity of the intestine, stimulates the synthesis of growth hormone, reduces the number of purulent complications and has a pronounced antioxidant capacity [18, 23, 27, 32].

The use of omega-3 and omega-6 polyunsaturated fatty acids in products for nutritional support is due to the need to optimize lipid metabolism [19, 23]. In the modern production practice of the studied products, omega-3 and omega-6 essential fatty acids of plant origin are mainly used, which is due to their higher organoleptic properties compared to similar animal origin [18]. It is known that additional advantages of their use in products for nutritional support of people with somatic diseases and injuries are the recovery and growth of muscle tissue, improvement of the rheological properties of blood by reducing its viscosity [18, 23].

Lecithin, consisting of choline, phosphoric and fatty acids, and glycerin, is also used in the production of nutritional support products [18, 19]. This component promotes the transport of nutrients from the blood to the cells, improves blood circulation by removing excess cholesterol, and helps restore immunity [18, 25].

Natural dietary fibers are widely used in the production of food products for nutritional support [27, 29], which is due to their prebiotic properties and ability to have a beneficial effect on the gastrointestinal tract due to the absorption of bile acids, cholesterol, and improve gastric motility [29].

An important factor determining the biological value of food products for people in an emergency, including the elderly, and trauma, is their vitamin and mineral value. To meet the metabolic needs of these consumers in micronutrients, individual artificially synthesized vitamins, their complexes, vitamin, vitamin-mineral and mineral premixes, mineral salts of a high degree of purification are most often purposefully added to nutritional support products [22, 25, 29]. Considerable attention in this process is paid to micronutrients characterized by antioxidant properties. In particular, vitamins retinol, ascorbic acid, calciferol, and tocopherol are most often used in the production of products for nutritional support of people in an emergency. Phylloquinone, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, cyanocobalamin are also used. In the production of products for enteral nutrition, mineral salts are also used, which are intended to meet needs. First of all, these are compounds that include Sodium, Potassium, Calcium, Magnesium, Ferrum, Copper, Zinc, Manganese, Chlorine, Phosphorus, Iodine [22, 28, 29, 32].

In view of the increased need for vitamins and mineral elements that contribute to the healing and restoration of the affected areas of the body, the trend of using raw materials containing nutrients in their native form – protein concentrates of milk whey, dry milk, egg white – has become widespread in modern practice [7, 18, 28, 29]. This is explained by the better degree of assimilation of nutrients by the body of affected people.

In the production of products for nutritional support, the vitamin-like coenzyme Q_{10} of natural and synthetic origin is often used, which is a natural antioxidant, provides energy to body cells,

protects fatty acids from oxidation by free radicals, stabilizes cell membranes and stimulates the immune system [18, 28].

It is appropriate to note one more group of raw materials for the production of the researched products – plant extracts. The most widely used are extracts of green tea, rose hips, chamomile, sage, and mint [25, 27, 29]. Such enrichment of products is explained by their properties – anti-inflammatory, healing, tonic, increased antioxidant capacity [27, 29]. In addition, in the modern practice of the production of special products, an extract of the Tribulus Terrestris plant is used, which contains mostly steroidal saponins of the furostanol type, among which protodioscin prevails, which is metabolized in the human body to dehydroepiandrosterone. It has been scientifically proven that this substance significantly contributes to the acceleration of muscle growth, activation of protein metabolism, increasing the level of permeability of cell membranes and immunity; improving cholesterol metabolism [29].

1.5 ANALYSIS OF EXISTING APPROACHES TO THE CLASSIFICATION OF PRODUCTS FOR ENTERAL NUTRITION

Nowadays, more than 250 names of products for enteral nutrition are produced in the world, which differ in a significant number of consumer characteristics and properties. The main ones are the specificity of the functional purpose, composition, energy value, the degree of decomposition of the constituent macronutrients, protein content, peculiarities of preparation for use (administration), physicochemical properties, and other characteristics.

An effective preventive means of protecting the rights of consumers, expanding and diversifying the range of products for enteral nutrition is the analysis of the existing classification bases and their comprehensive improvement due to the adaptation of modern world requirements and approaches. This will make it possible to study, evaluate and more fully satisfy the needs and expectations of target consumers; eliminate ambiguities, inaccuracies; ensure the industrial efficiency of manufacturing enterprises. It will also contribute to the intensification of international trade by eliminating technical barriers caused by the difference in approaches in global and national standardization systems.

According to the Law of Ukraine "On Basic Principles and Requirements for the Safety and Quality of Food Products" [37] enteral nutrition products are food products for special medical purposes. According to the mentioned document [37], they are defined as "food products specially designed and produced for feeding patients (including those who are infants and young children) to be consumed on the prescription of a doctor in a health care facility and/or outside its limits". At the same time, there is no classification of enteral nutrition approved at the legislative level in Ukraine.

Analysis of the experience of the European Union in the field of legislative regulation of the production and circulation of products for enteral nutrition makes it possible to define these products as a category of food products for targeted food use, developed and intended for dietary

nutrition of patients during treatment and recovery periods. European Union Directive 2016/128 "On specific requirements for the composition and information on food products for special medical purposes" [38] established the classification of enteral nutrition products according to their composition, according to which they are divided into 3 categories:

– with a standard composition, which, if used according to the manufacturer's instructions, can be the only source of nutrition;

– with a composition adapted to certain specific diseases, disorders or conditions of treatment, which, if used according to the manufacturer's instructions, can be the only source of nutrition;

– with a standard or adapted composition for specific diseases, disorders or treatment conditions that, when used according to the manufacturer's instructions, cannot be the sole source of nutrition.

In modern practice, the classification of products for enteral nutrition according to their chemical composition is considered the main one [29]. According to this classification feature, which is widely used in medical practice, the mentioned food products can be conditionally divided into 5 groups:

– *standard (polymeric)* – balanced in terms of their nutrient composition; to be used as both the only and additional source of nutrition. The main distinguishing feature of such products is that all macronutrients (proteins, lipids, carbohydrates) are in a single, unbroken form. Such enteral nutrition is prescribed in most uncomplicated cases, with the exception of pronounced disorders of digestion and assimilation of nutrients. In turn, the products of this group are divided into those that do not contain dietary fibers and those that do;

– *semi-elemental (oligomeric)* – balanced in composition and containing proteins hydrolyzed to peptides and/or amino acids; lipids to medium-chain triglycerides; carbohydrates to highly hydrolyzed dextrins. The products of this group are a good alternative to parenteral (intravenous) nutrition and are prescribed for disorders of intracavitary and parietal digestion caused by diseases or operations;

– *modular* – contain only one of the macronutrients or individual amino acids (for example, L-glutamine or L-arginine), fatty acid complexes (omega-3, omega-6), dietary fibers (pectin), regulators of the metabolic process (L-carnitine). They are used to supplement a special diet and meet the individual needs of each person;

– *special (metabolically directed)* – contain a composition of nutrients specially developed taking into account the most common physiological needs of specific physiological conditions or diseases (for example, hypermetacatabolism, diabetes, liver, kidney and severe respiratory insufficiency). The use of products of this group is aimed at correcting metabolic disorders;

– *immunomodulating* – intended for correction of immune disorders of victims with significant injuries and burns, severe infections, immunodeficiency. The composition of these products is enriched with special nutrients that strengthen immunity – L-glutamine, L-arginine, omega-3 and omega-6 polyunsaturated fatty acids, nucleotides.

Such classification of products for enteral nutrition, in our opinion, will help consumers (both victims and their doctors) to understand the wide range of similar food products sold in pharmacies

and specialized stores. At the same time, not all information about the properties and mechanism of ensuring the special metabolic needs of the human body is clear and available. In particular, this classification combines the direction of action (standard or special), and the degree of breakdown of the constituent macronutrients (polymeric, oligomeric, monomeric) and the composition of the components.

Specialists of the American Society of Parenteral and Enteral Nutrition [5] proposed a classification based on the energy content of 1 ml of enteral nutrition. According to it, such products are divided into:

– hypocaloric (1 ml < 1 kcal);

– isocaloric (1 ml – 1 kcal);

– hypercaloric (1 ml > 1 kcal).

At the same time, specialists of the European Society of Parenteral and Enteral Nutrition [39] proposed a classification based on the energy content of 1 ml of enteral nutrition, which differs in its numerical values:

– hypocaloric (up to 0.9 kcal/ml);

– isocaloric (0.9–1.2 kcal/ml);

– hypercaloric (more than 1.2 kcal/ml).

This organization also proposed a classification based on the degree of cleavage of the main amount of the protein component. According to it, products for enteral nutrition are divided into:

– polymeric – the protein is presented in an uncleaved form;

– oligomeric (semi-elemental) – the protein component is represented by peptides;

– monomeric – the protein component is represented by amino acids [40].

Also, specialized scientists in the field of medicine [40] developed another classification, according to which products for enteral nutrition were divided into 3 groups depending on the protein content:

– hyponitrogenous (up to 35 g of protein per 1 liter of product);

– isonitrogenous (35–50 g of protein per 1 liter of product);

– hypernitrogenous (more than 50 g of protein per 1 liter of product).

Another classification feature proposed by scientists is physical properties. Thus, products for enteral nutrition were divided into powdered and liquid (ready-to-use). In addition, emulsions and suspensions were singled out among the last group [27].

The analysis of existing approaches to the classification of enteral nutrition products from the point of view of commodity science allows to summarize that they are not always scientifically based and take into account the current trends of market development, the specifics of many scientific principles of consumer and technological features. Thus, the existing classifications of the studied products need to be revised.

The need for adequate provision of the nutritional needs of each of the individual categories of victims, which is aimed at restoring the body and minimizing metabolic process disturbances, requires a differentiated approach in order to achieve the expected physiological effect.

Based on the analysis, systematization of existing features and selection of new ones, which are important for conveying the information necessary for target consumers, in particular representatives of older age groups in emergency situations (both victims and their doctors), about the properties of products for enteral nutrition, we developed a classification. It was based on faceted distribution, which provides for the parallel differentiation of products for enteral nutrition into independent classification groups. This allows it to be flexible, easily expand and deepen its representativeness.

Systematicity was chosen as the main indicator when choosing classification features, which will allow more precisely to reveal the properties and peculiarities of the physiological effect of products for enteral nutrition on the metabolic processes of the human body. This, in turn, will make it possible to use it both in the scientific and theoretical sphere, and in the practical one.

The methodological basis for the classification of products for enteral nutrition identified 2 main groups of features:

– consumption (method of consumption (use), ability to be the only source of nutrition, direction of action, nature of impact on the body, energy value, content of the protein component, degree of splitting of its main mass, regularity of product use, age of consumers);

– technological (physical properties of the product (form of sale), origin of the protein component, packaging dosage, type and material of packaging) (**Table 1.7**).

● **Table 1.7** Classification of products for enteral nutrition

Group of classification features	Classification features	Categories of products for enteral nutrition
1	**2**	**3**
CONSUMABLES	Method of consumption (use)	– for oral consumption (sip feeding); – for tube feeding; – for combined consumption (use)
	The ability to be the only source of nutrition	– capable of being the only source of nutrition; – an additional source of nutrition is necessary
	Direction of action and associated diseases and/or lesions	– standard; – special: 1) for patients with diabetes; 2) for patients with damage to the cardiovascular system; 3) for patients with respiratory failure; 4) for patients with neurological diseases; 5) for patients with diseases of the gastrointestinal tract and/or dysbacteriosis; 6) for patients with endocrine diseases; 7) for patients with kidney failure; 8) for patients with liver failure; 9) immunomodulating

Continuation of Table 1.7

1	2	3
	Nature of influence	– indirect influence; – complex action; – direct impact; – monoaction
	Energetic value	– hypocaloric (up to 0.9 kcal/ml); – isocaloric (0.9–1.2 kcal/ml); – hypercaloric (more than 1.2 kcal/ml)
	Content of the protein component	– hyponitrogenous (up to 35 g/l of product); – isonitrogenous (35–50 g/l of product); – hypernitrogenous (more than 50 g/l of product)
	The degree of cleavage of the main amount of the protein component	– polymeric; – oligomeric (semi-elemental); – monomeric
	Regularity of use	– for regular use; – for long-term use; – for short-term use; – for one-time use (quick satisfaction of nutritional needs at a specific stage)
	Age of consumers	– for children aged 1–3 years; – for children aged 4–6 years; – for teenagers (ages 7–18); – for adults (18–60 years old); – for older age groups (over 60 years old)
TECHNOLOGICAL	Physical properties (form of implementation)	– liquid ready for consumption (use); – liquid concentrates; – powdered
	The origin of the protein component	– based on milk proteins (casein and/or whey proteins); – based on milk proteins (casein and/or whey proteins) and isolated soy proteins; – based on isolated soy proteins; – based on amino acids and peptides
	Packaging dosage	– for a single reception during the day; – for 3–5 receptions during the day; – for multiple (more than 5) receptions per day
	Type of packaging	– bottles, cans, bags, containers, stacks, etc.
	Packaging material	– glass, polymer and paper materials, plastic, metal, metallized foil, their combination, other

The proposed classification of products for enteral nutrition is based on the requirements established by specialized organizations in world practice (in particular, ASPEN and ESPEN),

advertising information of manufacturers, distributors and sellers, modern merchandising approaches to the classification of food products.

Thus, the proposed classification of products for enteral nutrition reflects the main approaches to their production and consumption, taking into account the interests and preferences of the target category of consumers and medical professionals. In turn, as the range of researched products in Ukraine and the world is updated and expanded, this classification can be supplemented and updated.

CONCLUSIONS

1. Based on the analysis of general approaches to meeting the nutritional needs of older age groups, it was established that for their full satisfaction, physiological processes caused by changes in metabolism during aging should be taken into account. It has been established that elderly, senile and long-lived people need a balance of the main nutrients, namely an increased amount of protein and lipid components and a reduced amount of carbohydrates. The diets of the studied group of people should have an increased content of dietary fiber, ascorbic acid, retinol, calciferol, tocopherol, thiamine, pantothenic acid, pyridoxine, calcium, phosphorus, magnesium, zinc, copper, selenium and chromium. This, in turn, is due to their ability to improve the digestion process, antioxidant properties and antisclerotic effect.

2. As a result of the analysis of the nutritional needs of representatives of older age groups in emergency situations, it was found that their full satisfaction largely determines the success of treatment and rehabilitation, it is necessary to take into account the specifics of metabolism and dietary principles. It was analyzed that in modern practice, specially developed food products, in particular products for enteral nutrition, are used for successful nutritional support of this category of persons.

3. Based on the results of the analysis of the peculiarities of meeting the nutritional needs of representatives of older age groups suffering from diabetes, in emergency situations it was determined that this process should be carried out taking into account the metabolic specificity. At the same time, taking into account the increased sensitivity to the carbohydrate component of the diet is of considerable importance, in connection with which the use of these components is limited. It is carried out using information about their glycemic index to prevent a significant increase in blood sugar.

4. It was established that the main raw materials appropriate for the production of enteral nutrition products are glucose, fructose, sorbitol, and other sugar substitutes; omega-3, omega-6 fatty acids, vegetable oils and extracts; proteins, peptides, amino acids, their concentrates. To increase the biological value of this product, the use of synthetic vitamins, their complexes, vitamin, vitamin-mineral, mineral premixes, mineral salts of a high degree of purification, taking into account their availability on the market, is also common.

5. Based on the analysis of existing approaches to the classification of products for enteral nutrition, the main characteristics by which these products are divided on the market were studied. Based on existing production and consumption approaches, a classification of products for enteral nutrition was developed, taking into account the specifics of commodity science. The proposed classification reflects the main approaches to their production and consumption, taking into account the interests and preferences of target consumers. In turn, as the range of researched products in Ukraine and the world is updated and expanded, this classification can be supplemented and updated.

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CHAPTER 2

JUSTIFICATION OF THE FEASIBILITY OF USING A2 MILK IN THE PRODUCTION OF SOME DAIRY PRODUCTS

ABSTRACT

The prospects of using A2 cow's milk in the production of dairy products were considered and analyzed. The object of research is the method of enriching A2 milk and the technology of hard cheeses made from raw milk from cows with different β-casein genotypes (A1A1, A1A2, A2A2). When digesting A2 milk, β-casomorphin-7 is not formed, which negatively affects the physiology of the gastrointestinal tract, cardiovascular, nervous and endocrine systems. It is recommended to use milk to which biologically active substances have been added, therefore the issue of its enrichment is relevant. In industrial conditions, artificial vitamin and mineral complexes are used to enrich milk. Taking into account that natural and synthetic substances act differently on the human body, it is proposed to use processed derivatives of carrots (Daucus carota) as a natural food additive. The use of carrot powders improves the amino acid spectrum of milk. The mass concentration of amino acids in A2 milk enriched with carrot peel powder was 4.87 g/100 g. The highest concentration, g/100 g, of glutamic acid (0.84), proline (0.50), aspartic acid (0.42), leucine (0.41), valine (0.35) was found. It was established that the consumption of 200 g of such milk provides the daily needs of the body in essential amino acids: threonine, leucine and phenylalanine (by 16 %), methionine (by 4 %), isoleucine (by 14 %), lysine (by 18 %), valine (by 20 %). It was established that A2 milk, enriched with powder from whole carrot roots, has a higher content of carotenoids (0.1068 mg/100 ml), providing the body's need for them by 1.4 %. Such milk can be an additional source of vitamin A produced in the human body. It is recommended to use powder from whole carrot roots for the enrichment of A2 milk in industrial conditions. Physicochemical indicators and cheeseability of milk of cows with different genotypes were studied. The content of fat, protein and solids in the milk of cows with the β-casein genotype A2A2 were slightly higher compared to A1A1 and A1A2. A comprehensive study of the quality indicators of hard cheese samples showed that the type of β-casein did not affect the sensory characteristics of the cheese. However, according to the content of the main chemical components, cheeses made from A1A2 milk had a higher content of dry matter and protein (on average, 61.6 % and 19.2 %, respectively) and a lower content of fat (37.2 %). The amino acid profile of cheese from the milk of cows with the β-casein A1A2 and A2A2 genotype showed a higher total content of amino acids –

14.89 mg/g and 13.84 mg/g, respectively. Calculations of cheese yield showed that cheese yield from milk of cows with β-casein genotype A1A2 was higher (mean value 13.1 %) than with A1A1 and A2A2. The obtained results are of practical importance, since it is possible to take into account how changes in the β-casein genotype in raw milk can affect the yield of cheese and, therefore, the profitability of production.

KEYWORDS

A2 milk, hard cheeses, enriched A2 milk, carrot powder, milk carotenoids, milk amino acids, β-casein A2, biological value, cheese yield, milk proteins.

CHAPTER 2

Milk is the first product in the diet of all mammals [1]. It is an affordable, popular and nutritious food product that contains a variety of important macronutrients. Milk contains about 3.2 % proteins, 4.8 % lactose and 3.5 % fat [2]. Every day, billions of people around the world consume milk and milk products, which play a key role in healthy nutrition and human development throughout life. Dairy products make up about 25–30 % of the average human diet.

At the same time, there is a large number of people who categorically refuse to drink milk. This is due to many factors, including the negative effects on the body when consuming milk and dairy products [3].

Adverse reactions to cow's milk are mainly described as intolerance to the lactose disaccharide contained in milk [4]. Lactose intolerance [5] and an allergy to dairy products are recorded in 65 % of the population. Eating dairy products that lead to symptoms of lactose intolerance usually results in temporary symptoms without harming the gastrointestinal tract.

According to the World Allergy Organization (WAO), 6–8 % of children under the age of 3 have food allergies, and 4.9 % of children have an allergy to cow's milk protein [6]. This food allergy is manifested by a wide range of clinical syndromes due to immunological reactions to cow's milk proteins [7]. Cow's milk allergy is an allergic reaction to the protein contained in cow's milk [8]. Allergy to cow's milk mainly occurs in childhood and often outgrows with age, although 15–20 % of allergic children become persistently allergic with elevated levels of immunoglobulin E (IgE).

Milk and milk products provide 18.1 % of the total daily protein requirement. Milk proteins are a heterogeneous group of polymeric compounds that have a wide range of different molecular structures and properties. About 30 % of the total protein contained in cow's milk is β-casein. It can be in different forms: A1A1, A2A2, or in the form of a combination of A1A2. The only difference between these two variants of β-casein (β-CN) is that the same position contains different amino acids. Type A1 contains histidine, which promotes enzymatic hydrolysis, and type A2 contains proline, which prevents proteolytic cleavage [9, 10]. The A2 variant is present in the milk of many mammals, including humans, goats, sheep and cows, while the A1 variant is present only in cattle.

Some studies have found that a key polymorphism in the β-casein protein may contribute to the association between cow's milk and human health [11–13]. Cow's milk protein is one of the most common allergens encountered by young children. Significant allergens are casein proteins (alpha-s1-, alpha-s2-, beta- and kappa-casein) and whey proteins (alpha-lactalbumin and beta-lactoglobulin).

It is known that milk allergens retain their biological activity even after boiling, pasteurization, ultra-high-temperature processing and evaporation for the production of dry infant formulas. The latest recommendations issued by the World Allergy Organization state that goat, sheep and buffalo milk should not be used as a substitute for children with an allergy to cow's milk.

Therefore, it is necessary to look for other ways to solve the problem of intolerance to milk and dairy products.

2.1 CHARACTERISTICS OF A2 MILK

In recent years, a new type of cow's milk has appeared on the market – "Milk A2". A2 milk contains only the A2 variant of the beta-casein protein. The history of A2 milk began not so long ago. At the beginning of the 20th century, in 2000, scientists from New Zealand investigated the value of A2 milk. It was New Zealand that patented A2 milk and began to take the first steps in spreading information about its benefits. However, for the first time A2 milk entered the market in Australia. It was there that other dairy products from A2 milk – cream, baby formula, ice cream, yogurt, etc. – were developed for the first time. In 2003, the production of A2 milk also started in the United States with considerable success.

A little later, in 2011, Great Britain joined the countries listed above. There, A2 milk was produced with the aim of extending the territory of the kingdom and Ireland. The first batches of A2 infant formula were sent to China in 2013.

Cows with the A2A2 gene produce only A2 milk. Cow breeds such as Jerseys, Guernseys, Normans and Brown Swiss have a higher percentage of the A2 gene than Holsteins. It takes many generations to form an A2 herd. In Ukraine, breeds in which the A2A2 genotype predominates include Lebedyn breed (**Fig. 2.1**).

The breed was bred to improve local peasant cattle (Ukrainian gray) and create hybrids of the Swiss breed. Milk from cows of the Lebedyn breed has an optimal ratio of milk fat and protein. Individuals differ in long lactation. Milk is a high-quality product with excellent taste properties.

Sales of A2 milk are growing rapidly, and Market Watch notes that the market is expected to grow by an average of 22 % by 2025. In addition to natural A2 milk, Nestle and A2 Milk companies began to specially manufacture A2 baby food, which is trusted by global experts and consumers in Australia, England, the USA and China.

Fig. 2.1 A cow of the «Lebedyn» breed

A2 milk and A2 dairy products are characterized by the fact that they do not contain the A1 variant of β-casein. A2 milk is natural cow's milk, which has a number of advantages in several respects, namely:

– milk containing only A2 β-casein has the potential to promote the production of the antioxidant glutathione in human blood plasma;

– mixtures based on A2 milk help to relieve children's colic and normalize metabolism;

– milk and dairy products A2 do not cause symptoms of neurological and mental disorders characteristic of opioids contained in food;

– when consuming A2 milk, people with lactose intolerance have fewer symptoms of gastrointestinal disorders;

– milk proteins A2A2 also increase the expression of the opioid receptor much less, compared to milk proteins A1A1;

– in the urine of patients with autism and schizophrenia, when consuming only A2A2 milk, the level of BCM-7 content decreases;

– consumption of A2A2 milk helps to prevent the risk of developing type 1 diabetes.

During the enzymatic hydrolysis of milk A1, the peptide β-casomorphin-7 (BCM-7) is formed, which is a known agonist of μ-opioid receptors. Beta-casomorphins are opioid molecules. The opioid system and its associated signaling pathways, feedback mechanisms, and physiological cascades are highly conserved across mammalian species, where it plays a diverse range of roles and interacts with many other important physiological systems.

Its impact on human health, including effects on the nervous and hormonal systems, early development, lactation, response to environmental stimuli, mother-child bonding, etc., is an extremely important topic in medicine and science and is still the subject of significant research and development.

It can directly affect the physiology of the gastrointestinal tract, as well as other parts of the body, for example, the cardiovascular, nervous and endocrine systems [14]. Lactose intolerance is often considered the cause of such disorders. However, there is increasing evidence that beta-casein A1A1 is also associated with cow's milk intolerance [15].

There are scientifically proven facts that consumption of milk with β-casein variant A2A2 prevents cardiovascular diseases [16] and prevents type 1 diabetes [17]. A2 milk contributes to the formation of less severe symptoms of autism and schizophrenia [18].

The negative impact of milk with the β-casein A1 genotype on human health is also highlighted in works [19–21]. The relationship between the β-casein A1 variant of milk and various diseases, neurological disorders such as schizophrenia, autism and sudden infant death syndrome has been shown. The link between neurological effects and BCM-7 depends on its ability to cross the blood-brain barrier and act as an opioid peptide. Its interaction with opioid receptors causes exorphin activity in the brain, which unfolds, for example, as a change in behavior, an analgesic effect, etc. An additional neurological outcome that was often investigated was the analgesic effect. Most studies compared this effect with other BCM fragments and investigated the opioid pathway to achieve the analgesic effect, including binding properties (e.g., opioid receptor affinity).

However, according to the authors [22], there is no convincing evidence that β-casein A1 in milk has an adverse effect on humans. This statement is also confirmed in [23]. Due to the ambiguous results of research on the effects of A1 and A2 milk on human health, it is impossible to clearly assess the functional significance of A2 milk, so further research in this direction is necessary.

Consumption of A2 has some functional advantages compared to A1, which are directly related to the effect of BCM-7 on human physiology. These functional properties are well established through extensive research over the past several decades.

Currently, most milk sold on the market contains a mixture of A1 and A2 β-casein, which can be obtained from heterozygous A1A2 cows or a mixture of milk from homozygous A1A1 and A2A2 animals.

The study of sensory quality, color and composition of A2 milk compared to A1 milk showed that different genotypes do not affect the smell, taste or general perception of milk. However, some differences were found in the color. The color parameters of A2 milk were closer to the gold standard color, which made it more attractive to consumers without artificial food colors. In dairy products made from milk from cows with the A2A2 genotype, the amino acid sequence of the protein is preserved regardless of the methods of its processing.

Milk must be obtained from healthy cows of genotype A2, in which no infectious diseases have been detected and which are under veterinary supervision. Milk must be produced in compliance with established hygienic requirements for the production of raw milk suitable for human consumption. Technical conditions for raw milk A2 have been developed A2 whole milk TU U 01.4-00447853-014:2022.

According to organoleptic indicators, milk must meet the requirements listed in **Table 2.1**.

Table 2.1 Organoleptic criteria of raw A2 milk

Name of indicators	Characteristic
Taste and smell	Clean, characteristic of fresh milk, without extraneous taste and smell
Color	From white to light cream
Consistence	A homogeneous liquid without flakes of protein and sediment

In terms of physical and chemical parameters, milk must meet the requirements listed in **Table 2.2**.

Table 2.2 Physical and chemical criteria of raw A2 milk

Name of indicators	Normalized values for varieties	
	extra	higher
Density (at a temperature of 20 °C), kg/m^3 not less than	1028.0	1027.0
Mass fraction of dry substances, %	≥12.0	≥11.8
Acidity		
°T	from 16 to 18.0	
pH	from 6.72 to 6.61	
Purity group, not lower than	I	
Freezing point, °C, not higher than	minus 0.520	
The temperature of milk during reception, °C, is not higher than	8	

After milking, the milk must be cleaned and cooled to a temperature no higher than 6 °C. For milk that will be processed at the enterprise no later than 2 hours after milking, the temperature is not set. Milk received at the processing plant is quickly cooled to a temperature not higher than 6 °C and stored at this temperature until processing.

According to biochemical indicators, milk must meet the requirements listed in **Table 2.3**.

Table 2.3 Biochemical criteria of raw A2 milk

Name of indicators	Normalized values for varieties	
	extra	higher
Allele C (A2) of the beta-casein gene (CSN2)	Present	
Allele C (A1) of the beta-casein gene (CSN2)	Missing	

Determination of allelic variants of the beta-casein gene (CSN2) should be carried out once a month, and if necessary, unscheduled. The producer of milk raw materials must guarantee that

this raw material is obtained from genotyped allele C (A2) of the beta-casein gene (CSN2), identified and registered animals, as well as the absence of inhibitors and adulterating substances.

Determination of biochemical (genetic) indicators of milk is carried out using molecular biological analysis – allele recognition analysis to determine the genotype of samples. The basis of the analysis is polymerase chain reaction (PCR) in real time. The analysis consists in quantitative detection of the fluorescent signal.

This type of analysis makes it possible to recognize the allelic polymorphism rs43703011 of the β-casein gene (CSN2) with the aim of further dividing cows by genotypes (A1A1, A1A2 and A2A2).

The purpose of allele recognition is to classify unknown samples as follows:

– homozygotes (samples containing only allele 1);

– homozygotes (samples containing only allele 2);

– homozygotes (samples containing allele 1 and allele 2).

When recognizing alleles, fluorescent dye-labeled probes specific for each allele are included in the PCR process.

The probes contain different fluorescent reporter dyes to detect the amplification of each allele.

According to microbiological indicators, milk must meet the requirements listed in **Table 2.4**.

Table 2.4 Microbiological criteria of raw milk

Name of indicators	Normalized values for varieties	
	extra	higher
Number of mesophilic aerobic and facultatively anaerobic microorganisms (KMAFAM), thousand CFU/cm^3	≤100	≤300
Number of somatic cells, thousands/cm^3	≤400	≤400

According to safety indicators, A2 milk must meet the requirements specified in **Table 2.5**.

For the production of A2 whole milk, whole raw commercial milk is used, obtained from cows with the A2A2 genotype, when purchased from dairy farms, collective agricultural enterprises, private and farm households, regardless of the form of ownership and types of activity.

Considering that A2 milk and A2 milk products have a higher value in the world compared to conventional milk products, increasing the production of A2 milk products will contribute to increasing the profitability of the dairy sector.

The purpose of the study is to develop a method of enriching A2 milk with amino acids, carotenoids and to determine the influence of the protein composition of raw milk on the yield of hard cheese and its nutrient content. This will make it possible to increase the biological value of A2 milk and reduce the manifestations of allergic symptoms when consuming it, as well as selectively select dairy breeds of cows suitable for cheese production according to their protein composition.

Table 2.5 Safety indicators of milk

Name of indicators	Normalized values for varieties
The content of toxic elements, mg/kg, no more than:	
the culprit	0.1 (0.05)
cadmium	0.03 (0.02)
arsenic	0.06
mercury	0.005
copper	1.0
zinc	5.0
Pesticides, mg/kg, no more than:	
hCG (gamma isomer)	0.05
Hexachloran	0.05
Antibiotics, no more than:	
Tetracycline, units/g	0.01
Streptomycin, units/g	0.01
Penililine, units/g	0.5
Content of radionuclides, Bq/kg, no more than:	
cesium Cs^{137}	100
strontium Sr^{90}	20
The content of mycotoxins, mg/kg, not more than:	
aflatoxin B_1	0.001
aflatoxin M_1	0.0005
Nitrates, mg/kg, not more than	10
Hormonal drugs mg/kg, no more than:	
diethylstilbestrol	Not allowed
estradiol-17	0.0002

To solve the set goal, the following tasks should be performed:

– analyze the amino acid composition of A2 milk enriched with carrot processing products;

– determine the content of carotenoids in A2 milk enriched with carrot root powders with and without skins;

– develop a scheme of A2 milk technology using waste-free use of dry carrot roots (without removing the skin);

– investigate the physical and chemical parameters of raw milk from cows with different genotypes for β-casein (A1A1, A1A2, A2A2);

– calculate and compare the yield of hard cheese from the milk of cows with different genotypes according to β-casein;

– investigate the organoleptic and physico-chemical parameters of samples of hard cheeses made from the milk of cows with different β-casein genotypes;

– establish the amino acid profile of hard cheeses from the milk of cows with different genotypes according to β-casein.

The object of research is the method of enriching A2 milk and the technology of hard cheeses made from raw milk from cows with different β-casein genotypes (A1A1, A1A2, A2A2).

Subjects of research: physicochemical indicators of raw milk from cows with different genotypes for β-casein (A1A1, A1A2, A2A2); yield of hard cheese from this milk and its quality indicators.

Research hypothesis: consumption of milk containing only β-casein A2 will reduce allergic manifestations; the use of a natural food additive to enrich milk with useful nutrients will contribute to their better assimilation by the body; the technological properties of raw milk depend on several factors, including genetic variations of proteins. The positive functional properties of A2 milk, the increase in the proportion of cows with the A2A2 genotype determine the expansion of the assortment of dairy products, in particular cheeses. It is assumed that the study of the influence of the protein composition of raw milk on the yield of hard cheese and the content of nutrients in it will make it possible to selectively select dairy breeds of cows suitable for the production of cheese according to their protein composition.

2.2 METHOD OF INCREASING THE BIOLOGICAL VALUE OF A2 MILK

Milk is an attractive product for fortification because it has a high nutritional density in a small volume and relatively low price.

The biological value of milk can also be improved by enriching it with functional nutrients. Dairy products enriched with trace elements usually contain calcium, phosphorus, magnesium, iron, zinc, copper, manganese, selenium, iodine, chromium, molybdenum and cobalt. In addition, milk is enriched with vitamins A, D, C, E and K and biotin, pantothenic or folic acids [24].

It has been established that milk enriched with micronutrients can be an effective means of reducing anemia in children under three years of age in developing countries [25]. Most of these biologically active substances are manufactured artificially in industrial conditions. They help to adjust the chemical composition of the product, but are not used by the body in the same way as their natural counterparts. In addition, their excessive use can be harmful.

The addition of linseed oil, phytosterols, and polydextrose had a positive effect on the physicochemical and organoleptic properties of milk. Such milk was well stored at refrigeration temperature for 1 week, having almost unchanged organoleptic, physicochemical and microbiological properties [26]. But the use of vegetable fats increases the fat content of milk, which does not meet the needs of some consumers.

Milk enrichment allows not only to increase the biological value, but also to increase its added value. The work [27] shows the results of research on the decrease in demand for plain, pure milk and the growing tendency to increase the consumption of flavored milk of medium and high fat content. However, artificial flavors should not be used in baby food.

Enriching milk with vitamin A and giving it certain organoleptic properties is possible due to the use of carotenoids. It is known that carotenoids have antioxidant properties, provitamin A activity, immune, endocrine and metabolic activity, play a role in cell cycle regulation [28].

Therefore, milk enriched with carrot carotenoids has better storage capacity. Apparently, this is due to the fact that β-carotene slows down microbiological processes. A natural source of carotenoids is carrot (Daucus carota), 35 % of the carotenoids of dry carrots are converted into vitamin A in the living organism. However, there are no industrial technologies for using carrots to enrich milk.

In industrial conditions, the vitamin complex FT 041081EU, which contains 12 important vitamins (A, D, E, C, Bc, B1, B2, B6, B12, PP, B5, biotin) and mineral FT 042836EU, is used in industrial conditions to enrich dairy products. which includes Fe, Zn and I [29]. It is not yet clear how successfully synthetic biologically active substances are assimilated and used by the body.

All this allows to state that the existing milk enrichment technologies mainly involve the use of synthetically created vitamin and mineral complexes. There is practically no assortment of milk with the use of natural food additives. Despite the fact that natural vitamins are absorbed much better than synthetic ones [30].

The biological value of milk is also determined by its amino acid composition, since amino acids participate in the biosynthesis of cells, which is very important for the vital activity of the human body [31]. It is advisable to increase the concentration of amino acids in milk due to natural additives.

Therefore, the development of a method of enriching milk containing β-casein A2 with natural food additives is an urgent issue.

A technique for enriching A2 milk with carrot powders has been developed (**Fig. 2.2**). Initially, it is recommended to conduct a molecular biological analysis of the milk of various cows to determine the form of β-casein. It is recommended to separate cows with the A2A2 genotype from animals with other genotypes in order not to conduct molecular biological analysis of each batch of milk. For the purpose of periodic monitoring, it is advisable to analyze the milk 1 time per month.

Determined milk β-casein in milk samples used in the experiments by a molecular biological method, which is based on a real-time polymerase chain reaction using the 7500 Fast Real-time System (Applied Biosystems) test system. This type of analysis makes it possible to recognize the allelic polymorphism rs43703011 of the β-casein gene (CSN2) by genotypes (A1A1, A1A2, and A2A2). Alleles were recognized using fluorescent probes (Taq Man) specific to each allele, marked with dye. Taq Man Universal PCR Master Mix reaction mixture, electronic dispensers with adapter, and mechanical variable volume dispensers (20–200) μL, (200–1000) μl were used.

After assessing the quality of milk, it matures in tanks within 24 hours. After the aging process, the milk is heated and separated. The cream selected during the separation process is cooled

and stored for no more than 6 hours. Some of it is used to normalize milk and dairy products, and some is used for the production of butter.

The normalized mixture is cleaned and homogenized at a pressure of 18–20 MPa. A homogenized milk mixture enriched with carrot powder is sent for pasteurization. Pasteurization of the mixture is carried out for 10–15 minutes at a temperature of 70–75 °C. Pasteurized milk is filtered and subject to ultra-pasteurization at a temperature of 150 °C for 5 seconds. Pasteurized milk is quickly cooled to 0–4 °C, packaged and sent for storage. It is recommended to use carrot powder made from whole roots (10 % by weight of milk) since the peels contain a large number of useful nutrients.

Carrot pulp is recommended to be used in the production of fermented milk products as a food additive. Enriched milk is pasteurized at a temperature of 90–95 °C for 15–20 s. After which it is cooled, packaged in consumer containers, and sent for storage. A feature of the developed technique (**Fig. 2.2**), involving the enrichment of A2 milk with carrot powder, is the waste-free processing of vegetables, in particular carrots; carrot pulp is proposed to be used as a food additive for the production of fermented milk products. The use of the proposed technique in production will expand the range of dairy products for functional purposes, in particular A2 products. This will partially solve the problem of ensuring the demand for medium-fat flavored milk.

The study used whole (fat content of 3.85) and skimmed A2 milk, obtained from cows at the vivarium of Sumy National Agrarian University. In addition, industrial samples of A2 milk made by Ichnianskyi Milk Powder and Butter Plant PJSC with a standardized mass fraction (2.5 %) of fat were used.

5 milk samples were analyzed (**Fig. 2.3**):

– whole A2 milk with a fat mass fraction of 3.85 % (Control);

– whole A2 milk (3.85 %) with the addition of 10 % powders made from peeled carrots (Sample 1);

– whole A2 milk (3.85 % fat) with the addition of 10 % powders made from carrot peels (Sample 2);

– skimmed A2 milk with the addition of 10 % powders made from carrot peels (Sample 3);

– industrial sample of A2 milk (2.5 % fat) with the addition of 10 % raw carrots (Sample 4).

For the manufacture of carrot powders in the laboratory, let's use carrots of the variety Shantane. Thoroughly washed root vegetables were disinfected with chlorine dioxide, rinsed with clean running water, peeled, and cut into slices (2 mm thick). Slices were dried at 50–60 °C for 2 hours in a 1.8 kW infrared laboratory dryer. After drying, the material was crushed in a disk mill LZM-1 and sifted through a brass sieve No. 015. Only a fraction less than 0.15 mm in size was used to enrich milk. In the same way, carrot peels were processed into powders.

Powders and fresh carrots, crushed into mush, were introduced into milk and thoroughly mixed for 30 minutes. Next, the enriched milk mixture was heated to a temperature of 70–75 °C and filtered. As filter partitions, filters for milk strainer FARMA (The Netherlands) with a diameter of 95 mm were used. Filtered enriched milk was pasteurized (t=90–95 °C, τ=15–20 s). Pasteurized milk was cooled to 20 °C and analyzed.

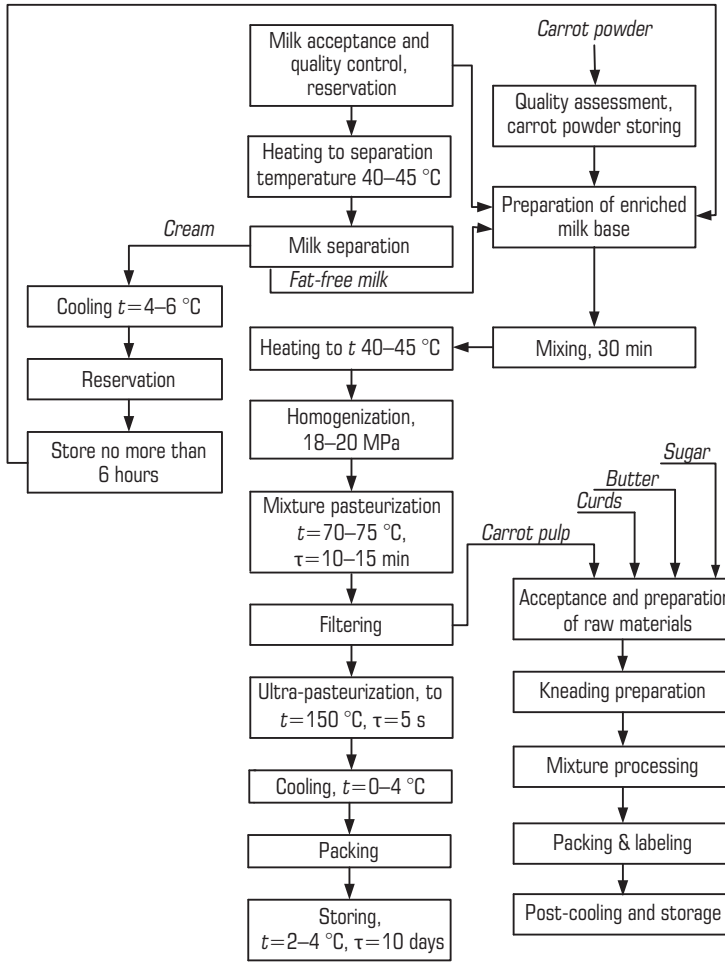

Fig. 2.2 Technological scheme of production of enriched A2 milk enriched with powdered carrot powder from unpeeled carrots (with peel)

It is possible to determine amino acids in the milk by the HPLC method using a liquid chromatograph Agilent 1200 (USA) by diode-matrix detection with a wavelength of 280 nm. The chromatographic division was the same and was carried out on column C18 at a temperature of 16 °C. Acetonitrile and acetate buffer (pH 6.0) were used as the mobile phase in the gradient elution mode

with an eluent flow rate of 1.0 ml/min. 18 amino acids were recognized in milk, including 7 essential ones (threonine, valine, methionine, isoleucine, leucine, phenylalanine, and lysine) (**Table 2.6**).

Fig. 2.3 Research samples of milk A2

The highest mass concentration of amino acids (4.87 g/100 g) was in whole A2 milk enriched with carrot powder made from carrot peels (Sample 2). It is worth noting that the concentration of amino acids in A2 milk without additives was 2.59 g/100 g. Most of all was found in Sample 2, g/100 g: glutamic acid (0.84), proline (0.50), aspartic acid (0.42), leucine (0.41), valine (0.35).

Sample 3, made on the basis of skimmed milk and carrot powder from the peels, also had a high content of mass concentration of most amino acids, compared to milk without additives (Control).

The amino acid composition of Sample 1 was slightly better than Control as there was an increase in the mass concentration of some essential amino acids. Namely, g/100 g: glutamic acid by 0.16; aspartic acid by 0.13; lysine by 0.09; valine, arginine, phenylalanine by 0.07; threonine, leucine, and isoleucine by 0.06; tyrosine by 0.05; serine and proline by 0.04; glycine and histidine by 0.02.

When using fresh carrots to enrich milk (Sample 4), compared to Sample 1 and Control, an increase in the mass concentration of proline by 0.05 and 0.09 g/100 g was observed, respectively. The concentration of aspartic acid in this sample by 0.15 g/100 g was higher than in milk without additives.

In particular, in the composition of milk enriched with carrot powder from carrot peels, a greater amount of glutamic and aspartic acid, proline, leucine and valine was found, compared with control. In addition, in the composition of prototypes of A2 milk, there is also an increase in the content of proline, leucine, and valine, that is, amino acids that ensure the assimilation of the protein complex. The use of 200 g of milk enriched with carrot powders will provide part of the daily need for essential amino acids (**Table 2.6**).

The daily requirement for threonine, leucine, and phenylalanine is provided by 16 %, methionine – by 4 %, isoleucine – by 14 %, lysine – by 18 %, valine – by 20 %. This fully coincides with the conclusions of many researchers. It is known that the following amino acids are indispensable for cows: Arg, His, Ile, Leu, Lys, Met, Phe, Thr, Trp, and Val. It is possible to identify 7 essential amino acids: threonine, valine, methionine, isoleucine, leucine, phenylalanine, and lysine.

Table 2.6 Mass fraction of amino acids in prototypes of A2 milk

Amino acid	Norm per day	Control	Sample 1	Sample 2	Sample 3	Sample 4
	g	g/100 g				
Aspartic acid	3	0.19	0.32	0.42	0.39	0.34
% of daily need		6	11	14	13	11
Threonine	2–3	0.09	0.15	0.21	0.20	0.17
% of daily need		4	6	8	8	7
serine	3	0.17	0.21	0.24	0.24	0.18
% of daily need		6	7	8	8	6
Glutamic acid	5	0.53	0.69	0.84	0.76	0.71
% of daily need		11	14	17	15	14
Proline	5	0.27	0.31	0.50	0.42	0.36
% of daily need		5	6	10	8	7
Glycine	0.3	0.04	0.06	0.08	0.07	0.07
% of daily need		13	20	27	23	23
Alanine	3	0.10	0.12	0.17	0.16	0.11
% of daily need		3	4	6	5	4
Cystine	2–3	0.01	0.02	0.03	–	0.01
% of daily need		0.4	0.8	1.2	–	0.4
Valine	3–4	0.16	0.23	0.35	0.31	0.24
% of daily need		5	7	10	9	7
Methionine	2–4	0.01	0.01	0.06	0.07	0.05
% of daily need		0.3	0.3	2	2	2
Isoleucine	3–4	0.13	0.19	0.26	0.23	0.20
% of daily need		4	5	7	7	6
Leucine	4–6	0.28	0.34	0.41	0.37	0.35
% of daily need		6	7	8	7	7
Tyrosine	1	0.11	0.16	0.20	0.19	0.16
% of daily need		11	16	20	19	16
Phenylalanine	2–4	0.13	0.20	0.25	0.22	0.19
% of daily need		4	7	8	7	6
Histidine	2	0.08	0.10	0.14	0.14	0.09
% of daily need		4	5	7	7	5
Lysine	3–5	0.21	0.30	0.34	0.32	0.27
% of daily need		5	8	9	8	7
Arginine	5	0.08	0.15	0.23	0.17	0.11
% of daily need		2	3	5	3	2

According to the proposed research hypothesis, the addition of carrot powder to A2 milk will help increase its carotenoid content. Such assumptions were made based on the results

of the analysis of information on the chemical composition of carrot powder and the effect of certain processing methods on the preservation of carotenoids. When homogenizing the milk-carrot mixture, carotenoids, which are part of the carrot powder, diffuse into the milk. This is evidenced by the change in its color. Thus, the product is enriched with natural pigments that are precursors of vitamin A and have antioxidant properties.

The organoleptic parameters of enriched milk A2 were determined and compared with the control sample. The appearance, consistency, color, taste and smell were determined organoleptically. The results of the study are presented in the form of a profile (**Fig. 2.4**).

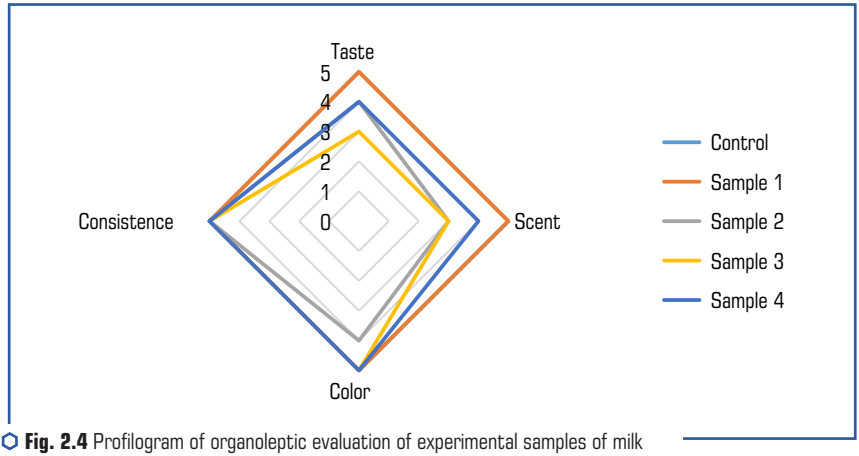

Fig. 2.4 Profilogram of organoleptic evaluation of experimental samples of milk

Unlike the Control sample and Sample 1, Samples 2 and 3 had a pronounced carrot odor. A slight smell of carrots was also observed in Sample 4. The results showed that when using carrot powders made from carrot peels, Samples 2 and 3 acquired a vegetable taste, which negatively affected the overall sensory properties of the product. However, the color of Samples 2 and 3 was very pronounced, creamy, similar to curdled milk. This color may indicate a higher concentration of carotenoids in A2 milk. The study showed that when using whole milk, the concentration of carotenoids in it was higher than when using skimmed milk. Considering that the samples enriched with carrot powder made from peels and raw carrots had a carrot smell, it is recommended to use 10 % carrot powder made from peeled root crops to enrich A2 milk. Some physicochemical indicators of the quality of milk A2 (Sample 1) enriched with 10 % carrot powder were analyzed. The results are presented in **Table 2.7**. The mass fraction of fat was determined by the gravimetric method. The mass fraction of protein is determined by the formol titration method, which is based on the neutralization of the carboxyl groups of monoaminodicarboxylic acids of proteins with sodium hydroxide solution.

The results of the study showed that the mass fraction of protein in enriched milk slightly increased (by 0.03 %).

● **Table 2.7** Results of the analysis of physicochemical parameters of A2 milk enriched with carotenoids ($n=3$, $p \leq 0.05$)

Name of indicators	Control	Sample 1
Mass fraction of fat, %	3.85±0.05	3.85±0.05
Mass fraction of protein, %	2.85±0.05	2.88±0.05

The mass fraction of carotenoids was determined by the chemical method. The batch of 15 g was placed in a round-bottom flask with a return refrigerator and hydrolyzed for 30 minutes in an alkaline-alcohol medium with constant boiling of the mixture and stirring. To prevent oxidation, 150 mg of ascorbic acid was added to the mixture. At the end of hydrolysis, the mixture was cooled and quantitatively transferred to the distribution watering can, adding distilled water. Extraction of non-washable substances from the mixture was carried out 3 times with diet ether, in portions of 50 ml. For further purification after evaporation of the solvent up to 20–30 ml, re-saponification was carried out. To do this, an equal volume of a 5 % alcohol solution of potassium hydroxide was added to the extract and reheated with a return refrigerator for 30 minutes in a water bath at the boiling point of the mixture.

The cooled solution was transferred to the distribution watering can, adding a small amount of distilled water to the separation of the layers. The top layer was washed 5–8 times with distilled water until a neutral reaction according to phenolphthalein, dried by adding anhydrous sodium sulfate, and evaporated on a rotary evaporator at a temperature of 30 °C to a volume of 3–5 ml. Further purification of carotene was carried out on a column with aluminum oxide containing 5 % water, using a chromatographic mixture of hexane-acetone (98:2) and a slight vacuum. Elution was carried out until the eluate became completely transparent, which was checked spectrophotometrically, using pure hexane as a control.

The eluate was evaporated dry on the rotary evaporator, the residue was dissolved in hexane, quantitatively transferred to a measuring flask with a volume of 25 ml, and the optical density of the solution was determined at a wavelength of 452 nm. The calculation of the mass fraction of carotene in the product was carried out taking into account the return coefficient. Previously, it was defined as the ratio of the amount of the carotene standard eluted from the column to the amount applied for chromatography, as well as the extinction coefficient E 1 % 1 cm=2500. Studies were conducted in several sequences, calculating the average result.

The results of determining the content of carotenoids in the studied samples are illustrated in **Fig. 2.5**.

The highest concentration of carotenoids was observed in Sample 2 (0.2435 mg/100 ml). Sample 1, which was found to be the most acceptable for consumption of all fortified A2 milk samples, contained 0.1068 mg/100 ml of carotenoids, which was significantly higher than that of the raw carrot-fortified sample and the Control sample.

The recommended rate of consumption of carotenoids, with an established physiological effect on the body – 15 mg per day, was used to evaluate the obtained research results.

Consumption of 200 g of milk enriched with carrot powder provides the body's need for carotenoids by 1.4 %.

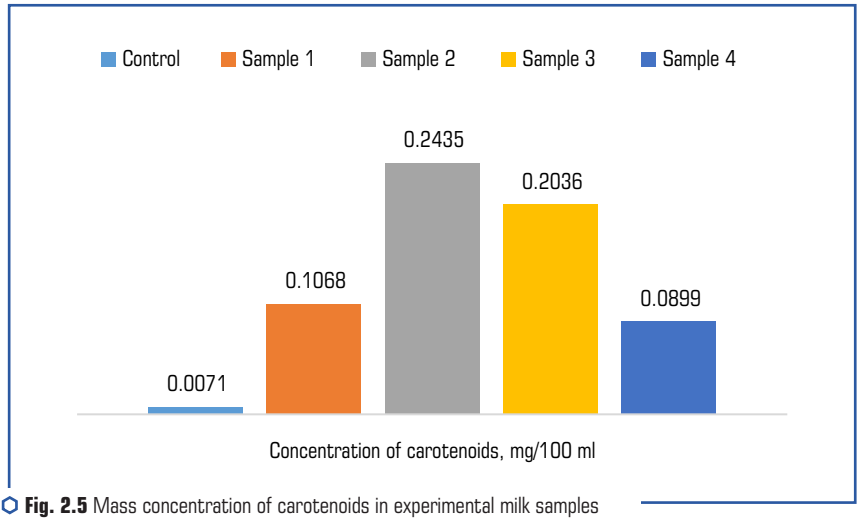

Fig. 2.5 Mass concentration of carotenoids in experimental milk samples

It is economically advantageous for the production of carrot powders to use carrots that are not peeled. At the same time, considerable attention should be paid to the preparation of raw materials for processing (washing, disinfection, and rinsing).

2.3 THE RAW SUITABILITY OF A2 MILK FOR CHEESE PRODUCTION

Cheese production accounts for the largest share of raw milk produced in the world (more than 75 %). The raw suitability of milk depends on the protein:fat ratio and the qualitative composition of casein. The β-casein composition of proteins is an important selection feature that affects the technical properties of milk [32, 33].

The growing proportion of cows with the A2A2 genotype in many countries has led to an increase in the mass production of "A2 milk" [34] and the need to expand research into the use of this milk in the production of dairy products, especially hard cheese.

Scientific research on this topic is important to understand the potential effect of β-casein A2 on cheesemaking and the relationship between genetic polymorphism and cheesemaking characteristics of raw materials. The results of such studies are needed in practice because they will make it possible to predict the yield of cheese from the milk of cows with different β-casein genotypes, to rationally use raw milk in production.

Work [35] reports the results of a marketing study on consumer preferences for A2 dairy products and evaluates the effect of β-casein A2 on the sensory characteristics of soft cheeses. It was shown that cheeses from the milk of cows with the β-casein genotype A2 were characterized by a creamier texture with a delicate structure compared to cheeses from A1 milk. However, consumers did not notice significant sensory differences in the products. The authors also indicated that consumers do not know about the usefulness of A2 milk. The reason may be insufficient awareness of this issue. The solution to this problem may be the development of marketing strategies to promote the benefits associated with A2 milk.

In cheese making, the key factors affecting the profitability of production are the amount and content of protein in raw milk. Monitoring all the relationships between the quality of raw materials and cheese production, such as the yield of cheese and the preservation of milk components in the cheese mass, is an important step to determine the efficiency of the entire technological process.

In [36], the results of the study into the determination of factors affecting the coagulation properties of cow, sheep, and goat milk are given. It has been shown that the amount and ratio of milk protein fractions strongly influence the coagulation properties of milk. The authors emphasize that genetic variations in milk proteins, especially casein, affect both the amount and proportions of different proteins in milk. But the question of the influence of genetic variations of β-casein A1 and A2 on the coagulation properties of milk remains unsolved.

This is the approach used in work [37]. The authors investigated the potential effects of β-casein genotypes A1 and A2 in percentage on cheese production. It was shown that with an increase in the relative content of β-casein A2 (>50 % of the total volume of milk), the yield of cheese decreased significantly; samples with β-casein A2 content below 75 % were characterized by a high content of nutrients. Thus, it was demonstrated that the amount of A1 milk ≥75 % in the milk mixture for cheese production has a beneficial effect on increasing the profitability of production. However, the authors did not take into account the fact that milk can come to milk processing enterprises in different quantities from cows with the specified genetic variations, which are difficult to control.

Work [13] reports the results of a study on determining the formation of a clot under the action of the rennet enzyme chymosin in the milk of cows of the Swedish red and white dairy breed. It was shown that milk from cows with β-κ-casein genotypes A1A2 and A2A2 coagulated worse with the formation of a weak clot compared to A1A1 milk. The result may be a lower yield of cheese during production. Similar results are highlighted in [38]. It was shown that the milk of Holstein-Friesian cows with the β-casein genotype A2A2 had a lower cheese yield compared to A1A1 and A1A2. The reason for this may be poor rennet coagulation of milk with β-casein A2A2. An option to overcome the relevant difficulties may be selective breeding of cows with the β-casein A1A1/A1A2 genotype.

However, the works reviewed above do not take into account that the production of cheese, namely the rennet coagulation of milk, is a complex process that is influenced by many factors: protein:fat ratio, acidity, type of rennet enzyme, etc. An option for improving the profitability

of the cheese industry is the genetic selection of dairy cows to obtain milk with good rennet protein coagulation. An indispensable characteristic is the preservation/restoration of nutrients in the finished cheese.

All this allows to state that it is appropriate to conduct a study on determining the complex effect of β-casein A1/A2 polymorphism and the chemical composition of milk on the production of cheese by evaluating the yield, content of nutrients, and chemical composition of cheese.

The aim of this study is to determine the influence of the protein composition of raw milk on the yield of hard cheese and the content of nutrients in it. This will make it possible to selectively select dairy breeds of cows according to their protein composition suitable for cheese production.

To achieve the aim, the following objectives were set:

– to investigate the physicochemical parameters of raw milk from cows with different genotypes for β-casein (A1A1, A1A2, A2A2);

– to calculate and compare the yield of hard cheese from the milk of cows with different genotypes according to β-casein;

– to investigate the organoleptic and physical-chemical parameters of samples of hard cheeses made from the milk of cows with different β-casein genotypes;

– to establish the amino acid profile of hard cheeses from the milk of cows with different genotypes according to β-casein.

The object of our research is the technology of hard cheeses made from raw milk from cows with different β-casein genotypes (A1A1, A1A2, A2A2).

Research subjects: physicochemical parameters of raw milk from cows with different genotypes for β-casein (A1A1, A1A2, A2A2); yield of hard cheese from this milk and its quality indicators.

Research hypothesis assumes that the technological properties of raw milk depend on several factors, including genetic variations of proteins. The positive functional properties of A2 milk, the increase in the proportion of cows with the A2A2 genotype determine the expansion of the assortment of dairy products, in particular cheeses. It is assumed that the study into the influence of the protein composition of raw milk on the yield of hard cheese and the content of nutrients in it will make it possible to selectively select dairy breeds of cows suitable for the production of cheese according to their protein composition.

A commercial herd of the Ukrainian black-spotted dairy breed in the Sumy region was chosen for the study. In this study, 10 kg of milk was collected during morning milking from nine cows with different β-casein genotypes (A1A1, A1A2 and A2A2). Raw milk was examined for quality indicators according to DSTU 3662:2018. The density of milk was measured by the aerometric method according to DSTU 6082:2009. Acidity (pH) of milk samples was determined by the potentiometric method according to DSTU 8550:2015. The mass fraction of dry substances in milk samples was determined by drying to a constant value of the indicator according to DSTU 8552:2015. The mass fraction of protein was determined by the Kjeldahl method according to DSTU ISO 8968-1:2005. The mass fraction of fat was determined by the acid method (Gerber method) according to DSTU ISO 2446:2019.

The results of determining the physicochemical parameters of test samples of cow's milk with different variations of β-casein, A1A1, A1A2, A2A2, are given in **Table 2.8**.

● **Table 2.8** Physicochemical parameters of raw milk samples with different genotypes ($n=3$, $p\leq0.05$)

Sample No.	Genotype of β-casein	Acidity, units pH	Density, kg/m³	Mass share of dry matter, %	Mass fraction of protein, %	Mass fraction of fat, %
1	A1A1	6.58±0.01	1026.0±1.0	12.54±0.02	2.93±0.1	4.34±0.01
2		6.55±0.01	1027.0±1.0	12.43±0.02	2.96±0.1	4.02±0.01
3		6.62±0.01	1026.0±1.0	12.65±0.02	2.85±0.1	4.66±0.01
4	A1A2	6.52±0.01	1026.0±1.0	12.47±0.02	2.95±0.1	4.26±0.01
5		6.56±0.01	1027.0±1.0	12.42±0.02	3.04±0.1	3.79±0.01
6		6.51±0.01	1027.0±1.0	12.45±0.02	2.93±0.1	3.97±0.01
7	A2A2	6.64±0.01	1026.0±1.0	12.24±0.02	2.97±0.1	4.66±0.01
8		6.65±0.01	1026.0±1.0	12.78±0.02	2.89±0.1	4.65±0.01
9		6.69±0.01	1025.0±1.0	13.08±0.02	2.88±0.1	5.07±0.01

The results of our study into the physical and chemical indicators of milk samples are typical for fresh cow's milk and meet the requirements of DSTU 3662:2018. The results of our studies into the physical and chemical parameters of milk samples (**Table 2.3**) did not reveal significant differences in the acidity and density of cow's milk with different variations of β-casein.

According to the results, the average value of dry matter content in milk samples from cows with the A1A1 genotype is 12.54 %, while the ratio of protein to fat content is in the range of 0.61...0.73.

In milk samples from cows with the A1A2 genotype, the average value of dry matter content is 12.41 %, and the ratio of protein to fat content is within 0.69...0.8.

The content of solids in milk samples from cows with genotype A2A2 is on average 12.93 %, and the ratio of protein content to fat is in the range from 0.56 to 0.63.

As a result of the study, it was established that milk samples with the A1A2 genotype had a higher level of protein:fat ratio (on average equal to 0.74), compared to milk samples with the A1A1 genotype (protein:fat – 0.67) and A2A2 (protein:fat – 0.61).

It is well known that the ratio of protein and fat in milk affects the yield and quality of cheese. For example, a protein to fat ratio of 0.7:0.8 will most likely result in a higher cheese yield. The authors of practically established that a high fat content in milk negatively affects the quality of cheese (moisture content increases), but at the same time, the yield of cheese increases. Conversely, when the protein content increases, the quality of cheese increases, but the yield of cheese decreases.

The investigated samples of hard cheese "Gouda" were produced from whole milk according to traditional technology in accordance with the requirements of DSTU 6003:2008 «Hard cheeses.

General technical conditions». Nine samples of cheese from cow's milk of different genotypes were prepared in parallel.

10 kg of raw milk was used to make cheese. Pasteurization, leavening, fermentation, and subsequent formation of cheese grains were carried out at a laboratory cheese factory.

The process of manufacturing samples of hard cheese "Gouda" under laboratory conditions consists of the following stages: milk purified from mechanical impurities is pasteurized at a temperature of (72–75) °C with a holding time of 20 seconds. In milk cooled to a temperature of (36±1) °C, dry leaven of direct application is added in the amount recommended by the manufacturer. Sourdough consists of mixed cultures of microorganisms – *Lactococcus lactis subsp. lactis*, *Lactococcus lactis subsp. cremoris*, *Lactococcus lactis subsp. lactis var. Diacetylactis* ("Dalton", Italy). Next, a calcium chloride solution (at the rate of 20–40 g per 100 kg of mixture) and rennet enzyme «Albamax 600» (100 % chymosin) are added (Caglificio Clerici, Italy). The mixture is fermented at a temperature of (36±1) °C until a dense clot is formed. Next, the clot is cut, the cheese grain is processed (kneading, second heating at a temperature of (39±1) °C, drying of the cheese grain). The formed cheese heads are pressed, then salted in brine (salt concentration, 18–20 %; temperature, 10–14 °C). The cheese is dried at a temperature of (10–12) °C for 4 hours. The dried cheese heads are covered with a protective coating «Polisved» and sent for ripening at a temperature of (12±2) °C for 30 days. Ripened cheese is stored in a refrigerator at a temperature of (6±2) °C.

Fig. 2.6 shows the appearance of samples of hard cheese made from the milk of cows with different genotypes (A1A1, A1A2, A2A2).

Cheese samples was examined for quality indicators according to DSTU 6003:2008. Acidity (pH) of cheese samples was determined by the potentiometric method according to DSTU 8550:2015. The mass fraction of dry substances in cheese samples was determined by drying to a constant value of the indicator according to DSTU 8552:2015. The mass fraction of protein was determined by the Kjeldahl method according to DSTU 5038:2008. The mass fraction of fat was determined by the acid method (Gerber method) according to DSTU ISO 2446:2019. Organoleptic indicators of cheese samples were determined according to DSTU 6003:2008, with recommendations described in the international standard ISO 22935-2:2023.

The results of the sensory analysis of the general characteristics of hard cheese (appearance, taste and smell, consistency, color, pattern on the section, shape of heads) by the expert group are represented in the form of a profilogram (**Fig. 2.7**).

According to the received sensory analysis profiles, the samples of hard cheeses from the milk of cows with the A1A1 genotype have an average appearance rating of 5.0 points. The taste and smell of the cheeses were rated at 4.0 points, the consistency – 3.7 points, the color – 4.3 points, the cut pattern – 3.7 points, the shape of the cheese heads – 5.0 points. At the same time, cheeses are characterized by experts as cheeses with a nice oval shape; with a good taste, but a weak aroma; with satisfactory consistency and uniform color; with an uneven arrangement of cells on the section.

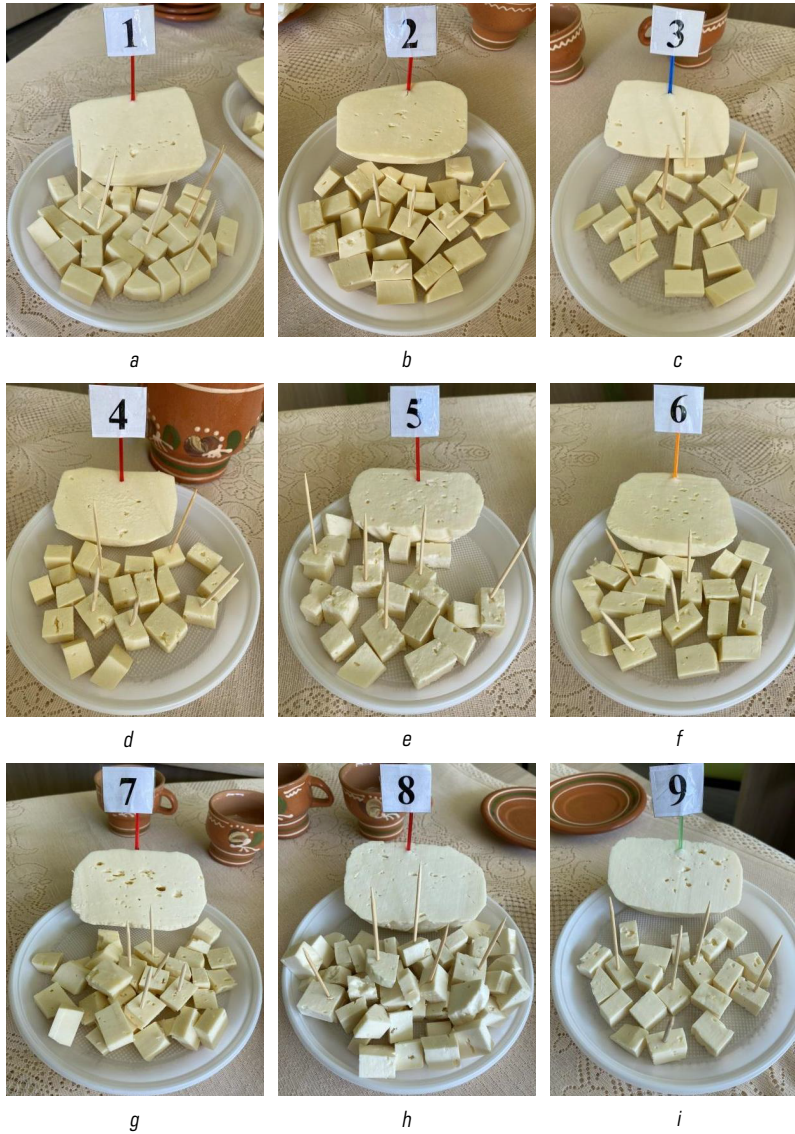

Fig. 2.6 Physical appearance of hard cheese samples: *a* – sample No. 1; *b* – sample No. 2; *c* – sample No. 3; *d* – sample No. 4; *e* – sample No. 5; *f* – sample No. 6; *g* – sample No. 7; *h* – sample No. 8; *i* – sample No. 9

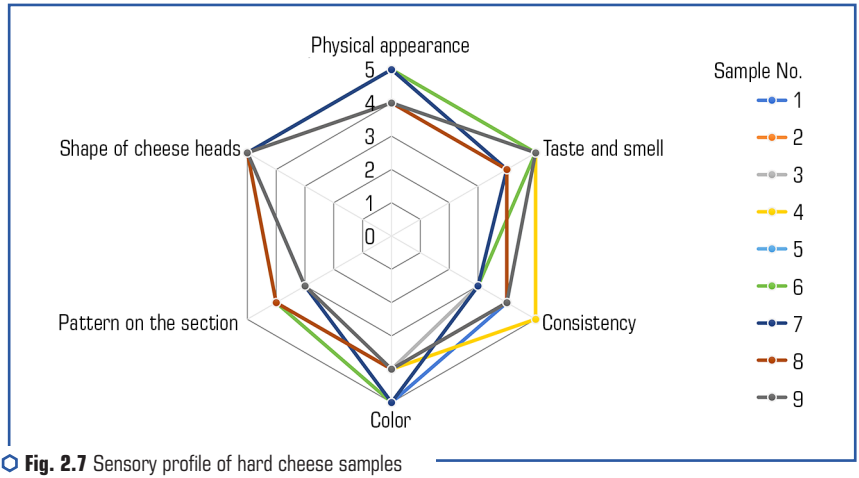

Fig. 2.7 Sensory profile of hard cheese samples

Samples of hard cheeses from the milk of cows with the A1A2 genotype were evaluated on average by their appearance – 4.7 points. Taste and smell of cheeses – 5.0 points, consistency – 4.0 points, color – 4.3 points, cross-section pattern – 4.0 points, shape of cheese heads – 5.0 points. Samples of cheeses have a good appearance; with excellent taste and smell; with a good consistency; uniform color and location of the cells on the section.

Samples of hard cheeses from the milk of cows with the A2A2 genotype have an average appearance rating of 4.3 points. Taste and smell of cheeses – 4.3 points, consistency – 3.7 points, color – 4.3 points, cross-section pattern – 3.3 points, shape of cheese heads – 5 points. Cheeses are characterized as satisfactory in appearance; with a good taste, but a weak aroma; with satisfactory consistency and uniform color; with an uneven slit-like arrangement of the cells on the section.

The results of the organoleptic analysis (**Fig. 2.7**) showed that variations in the β-casein genotype do not significantly affect the sensory characteristics of the cheese. Cheese samples made from milk from cows with genotypes A1A1 and A2A2 have significantly worse texture, taste and aroma compared to samples made from A1A2 milk.

The results of physical and chemical indicators of samples of hard cheese from milk with different genotypes are given in **Table 2.9**.

Changes in the β-casein genotype in cows had a noticeable effect on the chemical composition of cheese after 30 days of ripening (**Table 2.9**). The most noticeable were significant increases in the content of dry matter and protein in cheese samples from A1A2 milk (on average, 61.6 % and 19.2 %, respectively) and a decrease in fat content (37.2 %). Samples of cheese from A1A1 or A2A2 milk, on the contrary, were characterized by increased moisture (lower content of dry substances) and fat.

● **Table 2.9** Physicochemical indicators of samples of hard cheese from the milk of cows with different genotypes ($n=3$, $p \leq 0.05$)

Sample No.	Genotype of β-casein	Acidity, units pH	Density, kg/m^3	Mass share of dry matter, %	Mass fraction of protein, %
1	A1A1	5.13±0.01	61.7±0.02	21.1±0.1	36.1±0.01
2		5.13±0.01	62.8±0.02	22.4±0.1	35.8±0.01
3		5.17±0.01	61.3±0.02	20.9±0.1	36.3±0.01
4	A1A2	5.35±0.01	65.4±0.02	29.8±0.1	30.7±0.01
5		5.37±0.01	64.4±0.02	28.4±0.1	35.6±0.01
6		5.36±0.01	63.9±0.02	23.2±0.1	35.4±0.01
7	A2A2	5.23±0.01	62.5±0.02	19.8±0.1	37.2±0.01
8		5.24±0.01	61.6±0.02	18.7±0.1	38.1±0.01
9		5.26±0.01	60.8±0.02	19.1±0.1	36.3±0.01

The analysis of amino acids in cheese samples was carried out by the method of ion-exchange liquid column chromatography using the automatic amino acid analyzer "T 339" (Czech Republic, Prague). The following procedure was used: a weighed sample (with a protein content of about 2 mg) is mixed to the bottom of a test tube, 0.5 ml of distilled water and 0.5 ml of concentrated hydrochloric acid are added. The tube is cooled in a mixture of dry ice with acetone or liquid nitrogen. After the contents of the test tube freeze, air is pumped out of it using a vacuum pump to prevent oxidation of amino acids as a result of hydrolysis. Then the test tube is sealed and placed for 24 hours in a thermostat with a constant temperature (106±1) °C. At the end of hydrolysis, the test tube is opened, having previously cooled to room temperature. The contents are quantitatively transferred into a glass beaker and placed in a vacuum desiccator over granulated caustic sodium. Then air is removed from the desiccator using a water pump. After drying the sample, let's add 3–4 ml of deionized water to the cuvette and repeat the drying procedure. The sample prepared in this way is dissolved in 0.3N lithium citrate buffer (pH 2.2) and applied to the ion exchange column of the amino acid analyzer.

The averaged results are presented on a chart (**Fig. 2.8**). The study revealed 17 amino acid residues in hard cheese samples. Milk cheese samples A1A1 are characterized by a high content of essential amino acids, such as leucine (0.814...1.639 mg/g), lysine (0.672...1.295 mg/g), phenylalanine (0.451...0.914 mg/g), threonine (0.353...0.688 mg/g), histidine (0.232...0.467 mg/g), valine (0.276...0.543 mg). And there are also substitute amino acids, in particular, a high content of glutamic acid (2.193...3.098 mg/g), aspartic acid (0.741...1.335 mg/g), proline (0.929...2.092 mg/g), serine (0.524...0.986 mg/g), tyrosine (0.447...0.925 mg/g), and others.

Milk cheese samples A1A2 contain a high content of essential amino acids, such as leucine (1.174...1.724 mg/g), lysine (1.036...1.359 mg/g), phenylalanine (0.721...0.931 mg/g), threonine (0.547...0.7 mg/g), histidine (0.387...0.464 mg/g), valine (0.411...0.574 mg/g). And there

are also substitute amino acids, in particular, a high content of glutamic acid (2.895...3.398 mg/g), proline (1.276...2.256 mg/g), aspartic acid (1.035...1.33 mg/g), serine (0.867...1.005 mg/g), tyrosine (0.804...0.965 mg/g), and others.

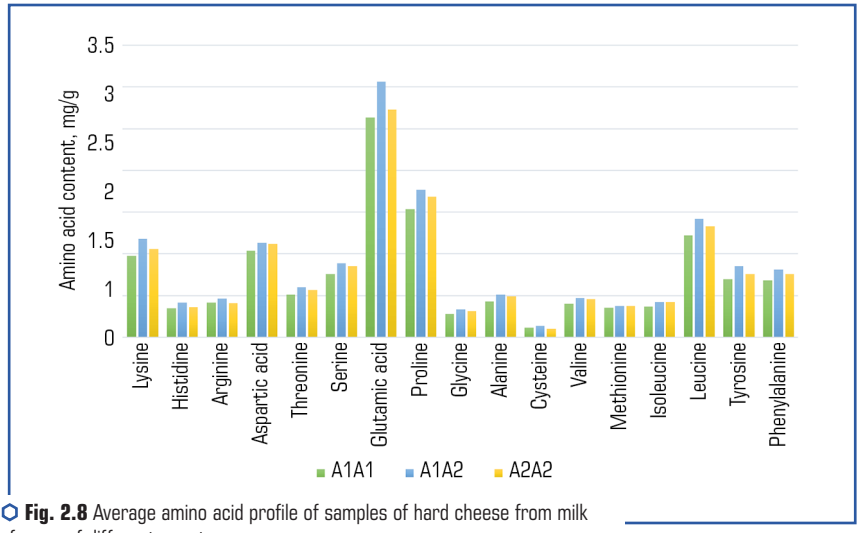

Fig. 2.8 Average amino acid profile of samples of hard cheese from milk of cows of different genotypes

A high content of essential amino acids was found in samples of A2A2 milk cheese: leucine (1.206...1.542 mg/g), lysine (0.931...1.225 mg/g), phenylalanine (0.693...0.861 mg/g), threonine (0.499...0.647 mg/g), valine (0.389...0.517 mg/g), isoleucine (0.355...0.489 mg/g). As well as replacement amino acids, in particular, a high content of glutamic acid (2.573...2.894 mg/g), aspartic acid (1.015...1.238 mg/g), proline (1.449...1.994 mg/g), serine (0.776...0.934 mg/g), tyrosine (0.676...0.862 mg/g), and others.

The results of the amino acid profiles of the experimental samples of hard cheese showed that the β-casein A2A2 genotype influenced the increase of the total content of amino acids in the finished cheese. In particular, A1A2 and A2A2 milk cheese samples had amino acid contents of 14.89 and 13.84 mg/g protein, respectively, which is relatively higher than that of A1A1 milk cheese (12.82 mg/g protein). Such results are explained by the difference in the amino acid profile of the original milk. According to data [39], A1A2 milk has a significantly higher content of essential amino acids (histidine, lysine, isoleucine, methionine, and valine) and conditionally essential amino acids (proline, serine, and tyrosine), as well as replaceable aspartic acid. A2A2 milk has a significantly higher leucine content compared to A1A1 and A1A2 milk.

The yield of hard cheese from the studied milk samples of cows with different genotypes (A1A1, A1A2, A2A2) was calculated according to the following formula:

$$B = \frac{m_{cheese}}{m_{milk}} \cdot 100\ \%,$$

where B – the yield of cheese, %; m_{cheese} – mass of cheese (30 days after production), kg; m_{milk} – mass of milk, kg.

The results are shown on a histogram (**Fig. 2.9**).

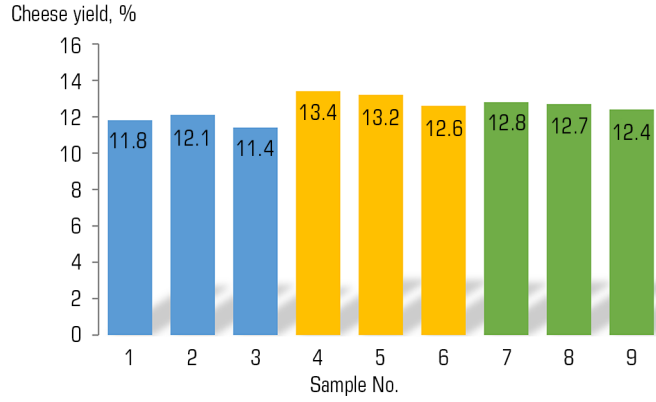

Fig. 2.9 Yield of hard cheese from the milk of cows with different genotypes

The averaged results showed the yield of cheese from A1A1 milk of 11.8 %; A1A2 – 13.1 %; A2A2 – 12.6 %.

The calculated yield of cheese (**Fig. 2.9**) showed that the yield of cheese from milk with β-casein genotype A1A2 was significantly higher (average value 13.1 %). This is related to the chemical composition and the optimal value of the protein:fat ratio (on average 0.74) in the original milk samples.

Comprehensive studies have shown that the β-casein genotype of cows has a significant effect on the nutrient content and yield of hard cheese from their milk. The information analysis clearly confirms that the consumption of cow's milk with β-casein A2 leads to an overall improvement in the condition of the gastrointestinal tract and a reduction in the intestinal discomfort associated with milk. However, significant differences in technological properties can be observed between A2 and A1 milk, and A2 milk has worse cheese-making properties.

The main limitations of the study are the analysis of raw milk from a commercial herd of the Ukrainian black-spotted dairy breed in the Sumy region. Methods of raising, keeping, and feeding Ukrainian cows (as a result of the composition of raw milk) may differ from countries with other climatic and cultural differences. However, the characteristics of raw milk based on genetic variations of milk proteins and cheese made from such milk can be applied to other countries.

The disadvantage of this study is that the study of the influence of the protein composition of raw milk on the yield of cheese was made only by the rennet coagulation method, using the example of Gouda hard cheese. Further research should investigate the cheese yield of several different technologies and methods of protein coagulation.

Our conclusions are of practical importance, as it can be taken into account that changes in the genotype of β-casein in raw milk can affect the yield of cheese and, therefore, the profitability of production. When conducting further research, special attention should be paid to the selection of rennet, the interaction of the variation of milk proteins with rennet and establishing the transition of protein substances into the serum. Incorrectly selected rennet, or its low quality, can reduce the practical value of the results.

CONCLUSIONS

1. The use of carrot powders makes it possible to increase the concentration of amino acids in A2 milk by 2.28 g/100 g, compared to the control. In prototypes of milk, the largest number of amino acids (glutamic, aspartic acids, leucine, valine) was found, which have a positive effect on the maintenance of vital body functions.

2. Research results showed that the highest concentration of carotenoids (0.1068 mg/100 ml) was observed in prototypes of milk enriched with powder from whole carrot roots. This indicates that the enrichment of A2 milk with carrot powder is an additional source of vitamin A, produced in the human body.

3. An industrial technique has been developed to increase the biological value of A2 milk with carrot powder. The expediency of using the developed technique is to use waste-free processing of raw materials. Carrot powders, under industrial conditions of dairy enterprises of Ukraine, can be added to A2 dairy raw materials.

4. Our research established that the physicochemical parameters of raw milk of cows with different genotypes of β-casein (A1A1, A1A2, A2A2) are typical for fresh cow's milk and meet the requirements of regulatory documents. The content of fat, protein, and solids in the milk of cows with the β-casein genotype A2A2 were slightly higher compared to A1A1 and A1A2.

5. A comprehensive study of the quality indicators of samples of hard cheeses made from the milk of cows with different genotypes showed that the type of β-casein did not affect the sensory characteristics of the cheese. However, according to the content of the main chemical components, cheeses made from A1A2 milk had a higher content of dry matter and protein (on average, 61.6 % and 19.2 %, respectively) and a lower content of fat (37.2 %).

6. The amino acid profile of cheese from the milk of cows with the β-casein A1A2 and A2A2 genotype in raw milk showed a higher total content of amino acids – 14.89 mg/g and 13.84 mg/g, respectively.

7. Calculations of the yield of cheese showed that the yield of cheese from milk of cows with β-casein genotype A1A2 was higher (average value 13.1 %) than with A1A1 and A2A2. These results are interrelated with the chemical composition of milk and the optimal protein:fat ratio in the original milk samples.

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CHAPTER 3

SCIENTIFIC AND PRACTICAL JUSTIFICATION OF INNOVATIVE APPROACHES TO PRODUCTION OF MULTICOMPONENT SEMI-FINISHED PRODUCTS FOR FOOD PRODUCTS IN THE CONDITIONS OF FOOD SECURITY OF THE COUNTRY

ABSTRACT

The production of functional products in the form of independent and multicomponent compositions based on vegetable semi-finished products of a high degree of readiness for further use during the manufacture of various food products is proposed. The proposed adaptive mechanism makes it possible to simulate the competitiveness of the agro-industrial sector in the conditions of taking into account the flow parameters of traditional micro- and macro-environments for the optimal adaptation of innovative approaches when implementing resource-saving hardware and technological solutions.

A resource-saving method for the production of multi-component puree-like semi-finished products with a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, beetroot and hawthorn has been developed. The hardware implementation of the resource-saving method is provided by the developed author's designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, ensuring uniformity of heat supply, stabilization of the temperature range, the possibility of using secondary heat energy. The proposed method is unified due to the implementation of the concentration process as needed in the form of a film flow (unified rotary-film apparatus), in a flow (unified tubular apparatus) and boiling in mass (unified vacuum-evaporation apparatus). Also, due to technological necessity, there is an additional technological operation of drying, which is implemented on a fundamentally new thermal radiation single-drum roller dryer.

The film-like electronic heater of the radiating type has been improved. Thanks to the improvement, the following technical properties of the film-like electronic heater of the radiating type have been achieved in terms of the maximum temperature of the working surface (40...180 °C). At the same time, the IR wavelength set from 2.0 to 15 μm with a power of up to 800 W/cm^2 and a technical efficiency factor (0.97) are optimal for heat and mass transfer processing of multicomponent vegetable semi-finished products. Thus, the reduction of: weight and specific metal capacity of the developed devices is ensured; duration of processing of thermolabile plant raw materials.

An equipment-technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness has been developed, which can be located directly on

farmland for the cultivation of natural raw materials. The practical implementation of the proposed innovative approaches in the production of semi-finished products will allow to support the own capacities of farmland, modernization of processing and production sectors of agro-industry. The resulting functional polycomponent semi-finished products will allow expanding the range of food products with an increased content of functionally physiological ingredients, predicted rheological and organoleptic properties. The introduction of developed semi-finished products into the recipes of various food products will reduce the need to use synthetic ingredients, replacing them with natural components.

KEYWORDS

Functional products, polycomponent semi-finished products with a high degree of readiness, competitiveness mechanism, concentration, drying, resource saving, film-like electronic heater of radiating type, structural and mechanical indicators, temperature field.

The implementation of scientific and practical innovative approaches in the agro-food sector is the key to the formation of food security of countries and the health of nations in the conditions of rapid adaptation of the processing and production chain to today's challenges (ecological, man-made, military, etc.). This will allow agro-industry to meet the rapidly changing needs of countries and consumer cooperatives during the production of food products and semi-finished products of increased physiological function with original rheological and organoleptic properties [1].

The use of one's own natural raw material bases (vegetable, meat, etc.) will make it possible to significantly reduce the dependence of countries in the international arena on existing import offers (recipe ingredients of synthetic origin and no benefit for human health). According to the "Sectoral Export Strategy of Ukraine for 2019–2023", the processing of natural raw materials is only 30 % of the volume of its collection from the areas of agricultural enterprises (920 thousand hectares) [2]. Today, this is explained not only by the lack of systematized, scientifically based solutions of a hardware and technological nature, regarding the processing of organic raw materials, it is especially complicated in the conditions of hostilities and the destruction of many infrastructure facilities. An important strategic task of ensuring the support of the own capacities of the agricultural sector, the processing industry and the food sector as a whole forms a strong economic export capacity of Ukraine with products of natural origin [3]. This will ensure international recognition on the world stage, prevent a food crisis in European countries and fill the country's budget, especially during full-scale military operations for rapid post-war recovery. When processing plant raw materials, attention should be paid to resource-saving processing with the use of secondary energy and the formation of rational methods of production of nutrient-based products with maximum preservation of natural properties. Ensuring the conditions for the production of our own polycomponent vegetable semi-finished products of a high degree of readiness with the subsequent introduction into the recipes of various food products, giving them predicted functional properties [4].

Traditional equipment of processing and production capacities of the agro-food sector needs modernization or the design of fundamentally new equipment to increase resource-saving operational and technological properties [5]. In particular, this applies to heat and mass exchange equipment based on intermediate coolants with increased energy and metal capacity, complicated stabilization of the temperature range and the use of additional generating devices and transportation networks. The use of heat-generating elements with fixed geometric dimensions, as well as intermediate coolants, leads to an artificial increase in the metal capacity of the equipment due to the formation of non-technological working zones. This, in turn, leads to an increase in the operational time of the devices reaching the working range and the consumption of converted thermal energy for heating the metal structures of the technological equipment of agro-industrial complexes. In addition, the existing traditional technological equipment based on the above-mentioned heat-generating elements is characterized by a low percentage of conversion of secondary thermal energy to further production needs, reducing the complex resource-efficient component of production sectors. As a result, a certain load on the country's primary resource component (gas, energy, etc.) is realized, which is difficult for the country's economy and enterprises in the conditions of full-scale military operations. Emphasizing the relevance of scientific and practical research aimed at finding, adapting and implementing innovative approaches under the conditions of comparing the technical properties of existing heat-generating elements for the formation of a resource-efficient component of heat and mass exchange equipment.

The use of traditional heat and mass exchange equipment forms the technological process and processing methods of the agro-food industry and is responsible for preserving the physiologically functional properties (quality) of the obtained natural semi-finished products and food products in general. This requires the introduction of modern innovative hardware and technological solutions based on qualitatively justified methods of heat supply, which are implemented on the main heat and mass exchange equipment with the use of gentle technological operations under the conditions of using secondary energy for production needs. Forming an urgent task of generalizing innovative hardware and technological solutions for the production of organic plant semi-finished products (dried fractional and pre-blended and powdered fractions) of a high degree of readiness. As well as food products based on them, allowing to obtain functional food rations of domestic origin under the conditions of using innovative equipment and technological approaches.

The production of health functional products by our own agro-industrial facilities in the form of independent and multi-component compositions based on vegetable semi-finished products of a high degree of readiness has a wide demand in the processing and food industries and in restaurants. In addition, it will make it possible to form a full-fledged diet in the post-pandemic and military period, thanks to the introduction of organic medical and preventive nutrition, in particular for people who are in extreme conditions (doctors, military personnel, etc.). Emphasizing the relevance of research aimed at the scientific and practical substantiation of processes and equipment for the production of organic vegetable semi-finished products of a high degree of readiness. And also, food products through the implementation of innovative energy-efficient hardware and technological

solutions aimed at obtaining products with a functional, adjustable nutrient composition from the moment of collecting raw materials to the sale of finished functional competitive products.

To solve one of the important tasks of Ukraine's national security in the conditions of military operations and rapid post-war recovery in the conditions of the majority of the population staying in extreme conditions and not having the possibility of daily full nutrition. An interdisciplinary project group was formed on the basis of the capacities of the State University of Biotechnology (Hero City Kharkiv), which, with the support of the Ministry of Education and Science of Ukraine, is implementing the state budget project "Development of hardware and technological solutions for the production of multi-purpose multicomponent organic semi-finished products and food products in the conditions of military operations and post-war reconstruction of the country". The main task of the project group is the development of innovative hardware and technological solutions for the production of multi-purpose multicomponent organic semi-finished products and food products under the conditions of using the country's own raw material base to support processing and production complexes in conditions of military operations. The obtained project solutions and results presented in the work are aimed at the possibility of further approval at the facilities of the EU countries due to the use of their own mechanisms and management systems for the organizational and legal security of agricultural enterprises of Ukraine.

3.1 THE URGENCY OF FINDING INNOVATIVE APPROACHES IN THE PRODUCTION OF MULTICOMPONENT SEMI-FINISHED PRODUCTS FOR THE FOOD SECURITY OF THE COUNTRY

Today's development of Ukraine in the conditions of full-scale military actions, in addition to defensive actions, is also aimed at strengthening national agricultural and food security, which can be realized at the expense of finding and implementing innovative approaches. Ensuring daily full nutrition of all segments of the population with simultaneous support of the agricultural sector is possible by growing one's own cheaper raw material base of natural (organic) origin [6]. With further comprehensive support of the country's processing and production capacities, the formation of resource-efficient mobile heating equipment will allow at the national level to maintain a full-fledged diet of the population of European countries. Preventing a decrease in the immunity of consumers, especially people who are in extreme conditions (military personnel of the Armed Forces, peacekeepers of the Alliance countries, doctors, volunteers, internally displaced persons, etc.) by using natural ingredients of plant origin, instead of synthetic components.

The introduction of multi-purpose multicomponent organic semi-finished products and food products based on them into the diet of the population requires innovative solutions to ensure high-quality prevention of environmental and military challenges, chronic and acquired diseases and pandemics. One of the ways to achieve this is the use of the domestic organic plant raw material base with further comprehensive support of agro-production complexes of Ukraine [7, 8]. Organic plant raw materials act as a natural source of functionally physiological ingredients

of health-improving action, possessing original structural-rheological and organoleptic properties necessary for the formation of original polycomponent semi-finished products. This will make it possible to produce high-quality natural functional and specialized semi-finished products of a high degree of readiness and food products for the daily diet, providing effective resistance to environmental and military factors and infectious, bacterial, cardiovascular, oncological diseases, etc.

3.1.1 PECULIARITIES OF THE COMPETITIVENESS FORMATION IN THE CONDITIONS OF PRODUCTION OF POLYCOMPONENT SEMI-FINISHED PRODUCTS FOR FOOD PRODUCTS

The dynamic system of the world economy allows taking into account various variable factors (needs of national security, raw material base, innovativeness of technology and the agro-industrial sector, assortment and novelty of goods, interest of consumer cooperatives, etc. [9]), including:

– ecological and technogenic factors, taking into account the locality of cultivation of own raw material base, industrial capacities of processing and production complexes for obtaining food products;

– technological factors of the agricultural sector (technologies: sowing, cultivation, harvesting), features of storage, transportation and methods of processing and conditions of sale to consumers;

– technological factors of the processing and manufacturing industry (territorial dependencies of the location of the raw material base, sources of heat energy, energy and metal capacity of heat equipment and the comprehensive level of resource efficiency);

– the efficiency of combined processing of agricultural raw materials in the conditions of mobile technological lines for the production of polycomponent semi-finished products with a high degree of readiness and food products based on them.

The generalized influence of the above-mentioned factors requires a quick reaction of the agro-industry of any European country, especially in the conditions of full-scale military operations and the world food crisis, and taking into account ecological, man-made and other situations. The development of the own capacities of agro-industrial complexes of European countries is a condition for the formation of national food security and international recognition of competitiveness due to the production of products of a wide range of use and demand. Unfortunately, the production of products using traditional energy- and metal-intensive hardware and technological solutions does not fully satisfy consumer demand for quality products at favorable prices offered by the manufacturer during sales. This leads to a decrease in the profitability and payback of production, including in terms of resource consumption (initial raw materials, transportation/storage costs, processing, production, spent thermal energy sources, etc.)

The adopted competitive program "Strategy for the development of agriculture in Ukraine for 2015–2020" combines 10 important strategic and priority directions aimed at supporting and developing the agricultural sector and the general development of the agro-food industry

for the formation of national food security [10]. Taking into account the current pricing factors in the conditions of taking into account the introduction of innovative resource-saving hardware and technological solutions into the own agricultural sector to obtain a competitive range of products to increase the country's export capacity. The analysis of the existing mechanisms of the formation of the agro-industrial market allows to find the necessary components of ensuring competitive conditions, taking into account business ethics, the needs of consumer cooperatives and recognition in the international arena. The use of innovative equipment and technological solutions in the formation of complex resource-saving solutions aimed at the cultivation of one's own natural raw material base, further supply to unified mobile processing and production complexes in the conditions of the optimal ratio of price and quality of products. A rational combination of the main components aimed at:

– the development of the agricultural sector for the cultivation of its own raw material base using innovative eco-technologies (sowing, cultivation, harvesting, etc.) allows obtaining organic raw materials on the country's chernozems even in conditions of military operations;

– the development of innovative approaches to the processing sector of agro-industry in terms of the use of zero-waste technologies in the processing of plant raw materials (use of seeds, skins, suitable waste (rubbing/cutting), etc.) in general production technologies. This will make it possible to obtain special natural semi-finished products (extracts, tinctures, recipe ingredients, etc.) at the processing stage for further use in many areas (pharmaceutical, food, etc.). In addition, in most cases, the waste of the processing complex of plant raw materials contains the original micro- and macro-elements necessary for the formation of consumer immunity and the body's resistance to environmental factors;

– the development and adaptation of the production potential to the needs of Ukraine today in the conditions of full-scale military operations through the use of resource-saving technologies aimed, among other things, at reducing the energy and metal consumption of traditional equipment.

Introducing into the country's production potential innovative hardware and technological solutions for the rational processing and production of organic raw materials grown in-house. This approach will make it possible to obtain original polycomponent semi-finished products of a high degree of readiness, which will have the properties of an independent product ready for consumption or recipe ingredients of various food products. Thereby minimizing the need to use traditional synthetic foreign ingredients (flavors, dyes, etc.) for natural multifunctional components with natural physiological properties, original organoleptic and rheological properties to obtain innovative food products. However, one should remember the need to implement technological processes under rational parameters, taking into account the impact of the energy and metal consumption of the hardware component, leading to the need to implement resource-saving hardware technological solutions.

Having considered the main components of the formation of the competitiveness of the agro-industrial environment in the conditions of the production of multicomponent semi-finished products for food products in the conditions of food security of the country in the target chain, a block diagram of the adapted mechanism of competitiveness management is proposed (**Fig. 3.1**).

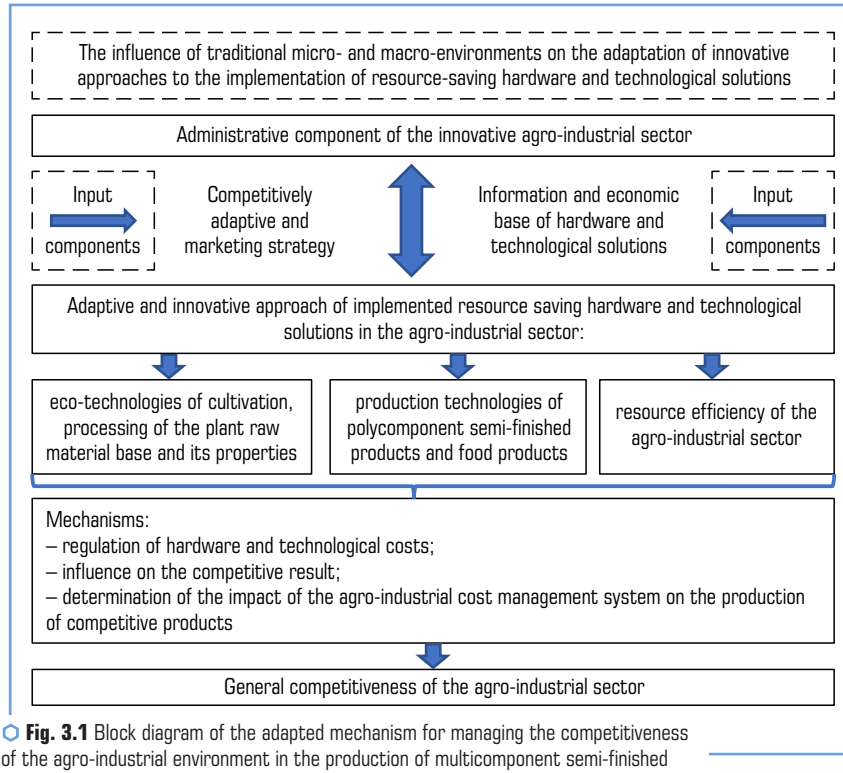


Fig. 3.1 Block diagram of the adapted mechanism for managing the competitiveness of the agro-industrial environment in the production of multicomponent semi-finished products for food products

The adaptive mechanism (**Fig. 3.1**) models the overall competitiveness of the agro-industrial sector by taking into account the parameters of the influence of traditional micro- and macro-environments on the adaptation of innovative approaches when implementing resource-saving hardware and technological solutions. The administrative component of the innovative agro-industrial sector takes into account input (resource, technological, equipment, etc.) and input (level of resource saving, originality of product range, cost, etc.) components. In the conditions of information exchange between the competitive-adaptive/marketing strategy and the information-economic base of hardware-technological solutions (technological maps, methods of processing/production, the level of efficiency of the adopted decisions, the investment-financial component of the adopted innovative approaches, etc.).

The proposed adaptive and innovative approach of implementing resource-saving hardware and technological solutions in the agro-industrial sector is aimed at taking into account:

– eco-technologies of cultivation and processing of raw plant base taking into account physico-chemical, rheological and organoleptic properties;

– optimal technologies (rational methods) for the production of polycomponent semi-finished products with a high degree of readiness and food products based on them;

– innovative solutions are aimed at resource-efficient processing and reduction of energy and metal consumption for the formation of resource efficiency of technological equipment.

At the same time, the control of the effectiveness of the adaptive-innovative approach was controlled by the mechanisms of regulation of hardware and technological costs and the impact on the competitive result, with the determination of the impact of the agro-industrial cost management system on the production of competitive products. Thus, the formation of the overall competitiveness of the agro-industrial sector was achieved, in the conditions of the production of multicomponent semi-finished products and food products for the country's food security in the target chain.

The efficiency of the adapted mechanism for managing the competitiveness of the agro-industrial environment in the production of multi-component semi-finished products and food products is effective under the following conditions:

– monitoring of the agro-industrial market at the international level to obtain information on trends in target sales markets, ways to improve marketing mechanisms to improve sales approaches, including using Internet resources;

– cyclical adaptation of the administrative component of the innovative agro-industrial sector under the conditions of the use of adaptive and innovative approaches to the implementation of resource-saving equipment and technology. Taking into account the environmental, man-made, military situation, etc. and the existing demand of consumer cooperatives and production efficiency while minimizing costs, forming a competitive price value and quality of the obtained products. This approach will make it possible to form the reach of the agro-industrial sector in the conditions of full implementation of manufactured products in accordance with the implemented adaptive-innovative hardware-technological approaches, and therefore to obtain a visible effect from the capital investments of the implementation of the proposed mechanism. Resource-saving production of plant-based polycomponent semi-finished products with a high degree of readiness and various food products based on them with original nutrient composition, rheological and organoleptic properties will ensure a competitive individual approach to consumer cooperatives. Increasing the demand for the consumption of the proposed assortment of products based on plant raw materials in the conditions of a combination of economic, man-made, situational and psychological factors, taking into account the data of marketing research on the behavior of potential consumers.

3.1.2 PECULIARITIES OF USING ONE'S OWN ORGANIC PLANT RAW MATERIAL BASE IN THE CONDITIONS OF PRODUCTION OF POLYCOMPONENT SEMI-FINISHED PRODUCTS FOR FOOD PRODUCTS

Since ancient times, the territory of Ukraine has been famous for its fertile chernozems and significant volumes of its own natural raw material base, in particular plant (fruit and berry, vegetable,

grain, spicy and aromatic, etc.), which in most cases is a source of natural physiologically functional ingredients. It has specific organoleptic and rheological properties, which, under conditions of rational blending, allow creating original multicomponent compositions with increased nutrient composition [11]. The use and processing of one's own raw resources of natural raw materials grown according to today's eco-technologies provides support to domestic farms and cooperatives, forming one of the components of the country's national security. The development of the agro-industrial sector has the support of the state in various programs and strategies of Ukraine-EU development, as it is an important exporter on the international market. The introduction of full-scale military operations on the territory of Ukraine reduces the intensity of the agro-industrial sector with existing traditional complex technological solutions. The implementation of resource-saving innovative approaches of agro-industry in the production of polycomponent semi-finished products with a high degree of readiness and food products based on them will ensure own food security and stabilize the international food crisis at the expense of export capacity [12]. In addition, it will make it possible to increase competitiveness, reduce the country's dependence on the international arena from import offers in the conditions of military operations, and obtain high-quality functional products for consumer cooperatives.

Natural plant raw materials grown on the chernozems of Ukraine according to traditional eco-technologies are cheap raw materials, except for the correspondingly selective varieties, but today's genetic technologies allow reducing the final cost of cultivation due to cultivation. Grown vegetable raw materials are a natural box of physiologically functional nutrient ingredients (FNI) with original rheological and organoleptic properties, which are necessary in the daily diet of the population to support/form and strengthen the immune component. However, if to consider plant raw materials: fruit, berry, vegetable, spicy-aromatic, etc. separately, they have certain "limited" FNI. Therefore, there is a need to conduct a number of experimental and practical studies aimed at determining the effectiveness and expediency of blending in order to obtain functional multicomponent natural semi-finished products of a high degree of readiness with predicted rheological and organoleptic properties [13].

In the course of analytical and experimental-practical complex studies, sample data were obtained to determine the expediency of mixing plant raw materials taking into account the natural features of plant raw materials [14]. During the studies of the effectiveness of the production of multicomponent blends, cheap domestic pectin-containing raw materials with a significant content of dietary fibers were chosen as the main plant raw materials: apple and Jerusalem artichoke. At the same time, its rheological properties act as a control during the comparison during blending of the structural and rheological properties of the semi-finished product (puree-like/paste-like). Raw materials with high carotene-containing and saturated coloring properties and FNI were selected as additional plant raw materials that were part of the blend [15].

Blending of the puree-like semi-finished product was carried out based on the calculation of the proportion of ingredients per 100 g of the test sample. At the same time, research was carried out for 3-, 4- and 5-component samples with the aim of forming a generalized idea about the formation

of rheological, FNI and organoleptic properties. A feature of the implementation of resource-saving methods of obtaining multicomponent puree-like semi-finished products is: rational blending of plant raw materials taking into account structural-mechanical, organoleptic and FNI properties under the conditions of using low-temperature methods of blanching, concentration, drying. For example, the recipe composition (**Table 3.1**) and the proposed method of production of polycomponent semi-finished products of high degree of readiness (**Fig. 3.2**) based on apple, Jerusalem artichoke, cranberry, beetroot and hawthorn are presented.

Table 3.1 Recipe composition of the 5-component puree-like semi-finished product

Recipe and component composition, %	Polycomponent pure-like semi-finished product		
	A	B	C
Apple	20	35	45
Jerusalem artichoke	20	25	35
Cranberry	30	20	10
Beetroot	15	10	5
Hawthorn	15	10	5
Control	100	100	100

An example of the proposed resource-saving method of production of multi-component puree-like semi-finished products of a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, beetroot and hawthorn (harvested in the territory of the Kharkiv region in 2023). The hardware implementation of the resource-saving method is provided by pre-developed proprietary designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, the uniformity of heat supply with a clear stabilization of the temperature range, the possibility of using secondary heat energy.

Ripe plant raw materials underwent traditional initial cleaning technological operations (washing, inspection, cutting according to technological needs, blanching). In accordance with the proposed technology, the hawthorn was kept in a 10...15 % NaCl solution with the addition of 1 % citric acid in a temperature range of 15...20 °C for 20...30 minutes to stabilize polyphenols. The selected raw materials underwent a short-term preliminary blanching operation in a universal multifunctional device [16], in particular with hot steam (103...115 °C): apple (1.5...3 min), Jerusalem artichoke (4...8 min), beetroot (8...10 min) and hawthorn (4...6 min). Blanching of cranberries was carried out with hot water for 1...2 minutes at a temperature of 85...90 °C, taking into account its natural consistency and FNI content.

Plant raw materials that have undergone the previous technological operation of blanching are sent to a universal wiping machine for wiping with the possibility of wiping components up to the size of 0.2...0.5 10^{-3} m. Waste obtained during wiping and cutting of vegetable raw

materials (skin, seed cell, bones, etc.) in order to increase the resource efficiency of the proposed technology are submitted to additional operations with drying in the IR field [12], extraction, etc. Extraction is suggested to be carried out for the first 4…8 minutes at a temperature of 70…75 °C with a further decrease in temperature to 55…70 °C. The technological operation of drying in the IR field is carried out at a temperature of 45…60 °C to the final moisture content – 6…12 % of the SR. This, in turn, makes it possible to obtain specific semi-finished products with original properties and a wide range of use in the pharmaceutical, processing and other industries in accordance with technological needs, replacing synthetic ingredients of foreign origin.

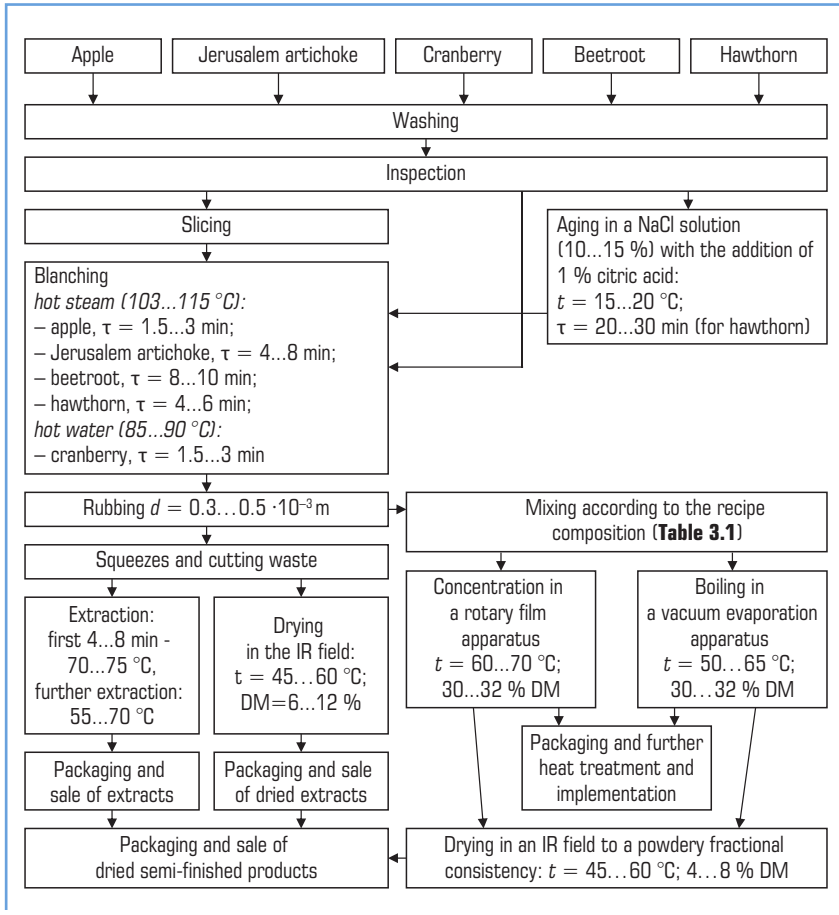


Fig. 3.2 The method of production of polycomponent semi-finished products with a high degree of readiness

After that, the homogeneous puree-like mass was sent to the mixing unit with a stabilizing thermal shell (unified reactor [17, 18]), in which the recipe mixing process of 5 components to a homogeneous state of a multi-component puree-like semi-finished product is implemented according to **Table 3.1**. A preliminary comparative analysis of organoleptic properties was carried out through evaluation by an expert group (5 people from the State Biotechnology University) of multicomponent puree-like test samples (**Table 3.2**)

Table 3.2 Results of expert assessment of organoleptic properties of multicomponent puree-like experimental samples obtained according to the recipe composition (**Table 3.1**)

Assessment index	Experimental polycomponent puree-like semi-finished product		
	A	B	C
Appearance	Homogeneous puree-like vegetable mass		
Taste and aroma	Harmonious taste of Jerusalem artichoke and apple, audible taste of cranberry, beetroot and hawthorn	Pleasant harmonious taste of Jerusalem artichoke with light notes of apple and cranberry	Pronounced smell and taste of Jerusalem artichoke in combination with apple
Color	Pronounced yellow-orange with a light red color	Pleasant yellow-light red/orange	A light shade of yellow-orange with a slight hint of red
Consistence	Homogeneous viscous consistency of uniform rheological structure		

A viscous consistency with a homogeneous rheological structure is formed as a result of mixing recipe vegetable purees into a multicomponent mass (spreading and separation of components is not observed). In terms of color and taste-aromatic indicators, blend B with the content of: apple – 35 %, Jerusalem artichoke – 25 %, cranberry – 20 %, beetroot – 10 % and hawthorn – 10 % is superior. Other experimental polycomponent puree-like semi-finished products (A and B) have more/less pronounced organoleptic properties of certain ingredients in terms of taste and color.

The formed homogeneous polycomponent puree-like mass was sent to the further technological operation of concentration. The proposed method is unified due to the implementation of the concentration process as needed in the form of a film flow (unified rotor-film apparatus [19]). The efficiency of using rotary-film evaporators is presented in experimental and practical works [20, 21]). Concentration can be carried out in a direct flow based on a film-like electric heater (unified tubular apparatus [22]) and boiling in mass (unified vacuum-evaporator apparatus [23]). The concentration process in a unified rotary-film apparatus is implemented under the conditions of a low temperature range (60...70 °C) to a paste-like state within 0.75...0.9 min., in a unified vacuum-evaporating apparatus at a temperature of 50...65 °C [24]. Regardless of the cooking method, the puree-like multicomponent mass was cooked to a pasty consistency with a content of 30–32 % DM, followed by packaging in a light-proof hermetic container with simultaneous heat treatment and sent for further sale. Packaging of the paste-like semi-finished product can be implemented in glass and

PET containers [25] depending on the technological needs and the way of use by consumer cooperatives, including significant attention is paid to the conditions of transportation/storage and use.

In order to visualize the obtained rheological properties of polycomponent semi-finished products when creating products with predicted structural and mechanical properties, it is necessary to determine them during concentration (boiling) with subsequent comparison with the control (apple puree). **Fig. 3.3** shows the properties of the ultimate shear stress of each component of the recipe composition of the future multicomponent semi-finished product (Θ, Pa).

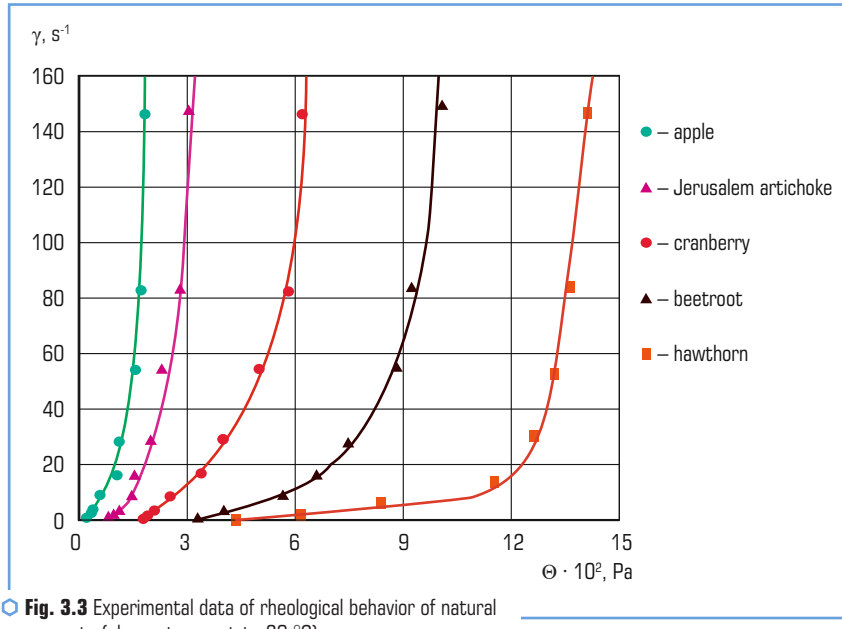


Fig. 3.3 Experimental data of rheological behavior of natural components (shear stress, at t=20 °C)

Thus, the control component of the future multicomponent puree-like composition has an ultimate shear stress of 15 Pa, Jerusalem artichoke – 320 Pa, cranberry – 70 Pa, beetroot – 85 Pa, and hawthorn – 440 Pa, respectively. In addition, for a complete picture of the rheological structure of polycomponent semi-finished products of plant origin, the dependences of dynamic viscosity on shear rate for puree and paste were obtained (**Fig. 3.4**, for the optimal blend B according to expert evaluation data, **Table 3.2**). The control was non-variable (apple puree/paste) with further comparison of the obtained rheological properties of the cooked pasty semi-finished product with a content of 30 % DM.

The analysis of the presented rheological parameters confirms the increase in the effective viscosity of the multicomponent sample B by 28 % compared to the control. In particular, test

sample B with the strength of the structure at the level of 440 Pa·s, compared to the control in the form of applesauce – 53 Pa·s. Boiling in a rotary-film apparatus at a temperature of 60 °C to 30 % DM made it possible to increase the strength by 3.4 times – 550 Pa·s, compared to the control (with apple paste 30 % DM – 175 Pa·s. Therefore, it is possible to draw a preliminary conclusion about the formation of a multicomponent plant experimental sample of high potential, increasing the effectiveness of its use as a natural additive or filler in various recipes of food products.

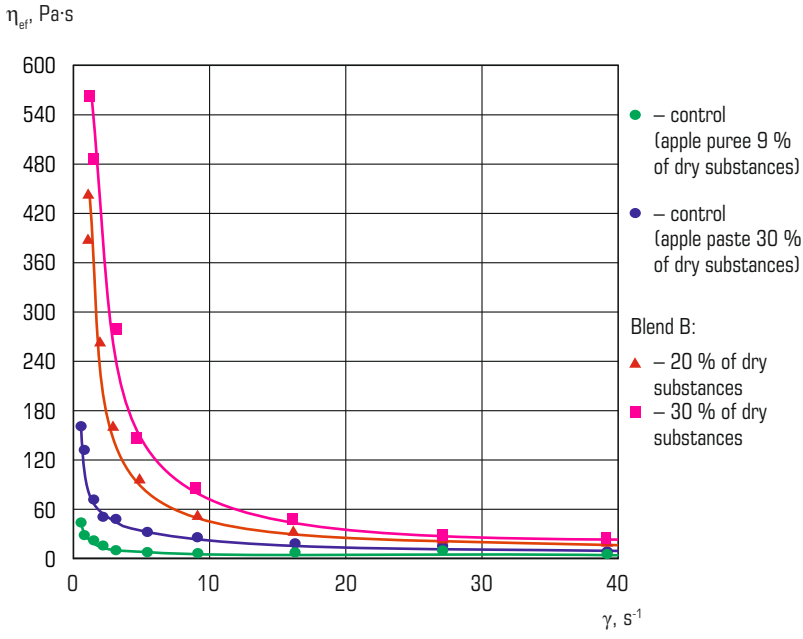


Fig. 3.4 Rheological curves of multicomponent vegetable semi-finished products (t=20 °C)

The obtained paste-like multicomponent vegetable mass is a semi-finished product of a high degree of readiness and can act as an independent product ready for direct consumption by consumer cooperatives [26]. Including by people who are in extreme conditions (military personnel, doctors, volunteers, tourists, etc.) and can be used as recipe ingredients in various food products [27], pharmaceutical products of the processing industry, etc.).

To expand the functional properties of the proposed production method, there is a possibility of drying the paste-like multicomponent products of a high degree of readiness to a powder-like

fractional consistency if technologically necessary. An additional technological operation of drying was implemented on the design of a fundamentally new thermal radiation single-drum roller dryer [28]. The peculiarity of the design is the preliminary heating of the strip-like polycomponent semi-finished product in the inner space of the corrugated drum and direct injection onto the corrugated surface by a special design of the trunnion. In addition, the device is equipped with autonomous fans to create a convective component in order to intensify the IR convective and conductive drying process. Drying in the IR field of a roller dryer to a powder-like fractional consistency is carried out under gentle temperature ranges (45…60 °C) to a dry matter content of 4…8 %. This approach will make it possible to obtain polycomponent semi-finished products of a high degree of readiness with the predicted FNI content, nutrient composition, structural-mechanical and organoleptic properties. Providing consumer cooperatives with innovative products of natural origin. The introduction of dried fractional polycomponent semi-finished products into the recipes of various food products will reduce the need to use synthetic ingredients, replacing them with natural components. To obtain a competitive range of products and to have new export capacities on international markets.

3.2 PECULIARITIES OF THE PRACTICAL IMPLEMENTATION OF PLANT RAW MATERIAL PROCESSING IN THE CONDITIONS OF THE IMPLEMENTATION OF INNOVATIVE HARDWARE AND TECHNOLOGICAL SOLUTIONS

Natural raw materials grown according to today's eco-technologies require the use of optimal methods of collection, transportation, resource-saving processing into semi-finished products of a high degree of readiness. In addition, further use in food formulations allows to artificially expand physiologically functional properties with predicted rheological and organoleptic properties [29]. However, taking into account the natural properties of plant heat-labile raw materials, there is a need to analyze traditional methods of storage and processing (**Fig. 3.5**) in order to find possible innovative approaches to resource-saving processing.

Our own vegetable raw material base for the production of polycomponent semi-finished products of a high degree of readiness is: fruits, berries, vegetables, spicy and aromatic raw materials, etc. and has traditional main methods of storage and processing. The disadvantages of the classic method of storage are:

– the need to take into account the factors of seasonality of raw materials and the expediency and efficiency of growing plant raw materials in greenhouse conditions;

– the need to create special storage conditions for plant raw materials (availability of resource-saving storage chambers and consideration of energy consumption);

– additional transport costs (from the place of collection to storage) and when moving from storage chambers to sales points in special technological modes;

– consumption of energy resources for storage, during transportation and at the time of sale.

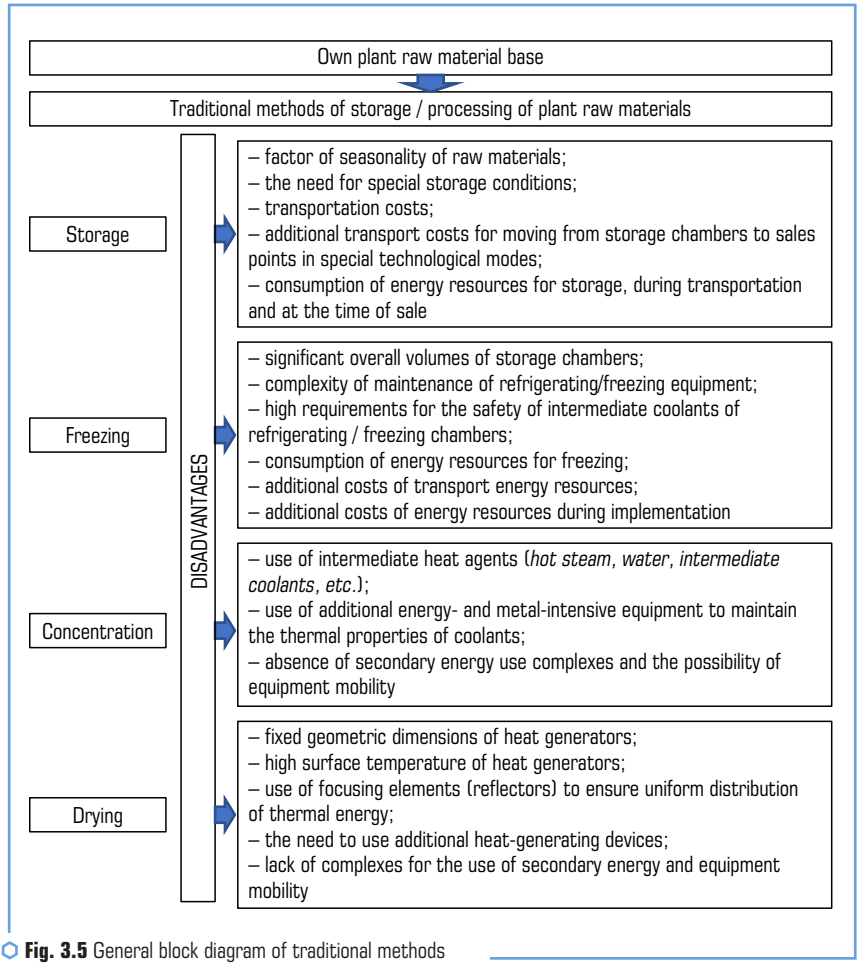


Fig. 3.5 General block diagram of traditional methods of storage/processing of plant raw materials

The technological process of freezing, including sublimation, has the following disadvantages:

– significant overall volumes of storage chambers and chambers for sublimation of plant raw materials;

– complexity of technical maintenance of refrigerating, freezing and sublimation equipment;

– high requirements for the safety of intermediate coolants of the equipment;

– costs of energy resources for freezing/sublimation and additional costs of transport energy resources and during frozen products.

Among the heat and mass transfer technological processes, concentration and drying (convective, conductive, microwave, infrared, etc.) are promising for the processing of plant raw materials [30], but they also have certain disadvantages related to design features:

– the use of intermediate heating agents (hot steam, water, intermediate coolants, etc.), which require the use of additional energy- and metal-intensive equipment to maintain the thermal properties of coolants;

– fixed geometric dimensions of heat generators and the use of technical networks for their transportation, including the need to use focusing elements (reflectors) to ensure uniform distribution of thermal energy on receiving surfaces (working chambers);

– lack of complexes for the use of secondary thermal energy and the possibility of equipment mobility due to the above-mentioned structural shortcomings.

Therefore, classic storage and freezing operations have more difficult conditions for the implementation of innovative approaches to intensification of equipment and technological approaches, in contrast to methods of concentration and drying. However, in order to find innovative approaches, in particular in the direction of constructive improvement of the equipment, it is necessary to consider the features of heat-generating elements. This approach will make it possible to substantiate optimal heat-generating elements that can allow: minimize (eliminate) the use of intermediate coolants with technical networks; to form rational working chambers with uniform distribution of thermal energy throughout the entire volume. This will, to some extent, increase resource efficiency and the possibility of finding ways to use secondary heat resources for production needs. The search for innovative approaches to the constructive improvement of heat and mass exchange equipment will simultaneously provide the possibility of realizing low-temperature gentle temperature ranges of processing, which is necessary for the maximum preservation of natural FNI of heat-labile plant raw materials.

Let's consider the features of the use of radiant-type electric heat-generating elements available on the market (**Fig. 3.6**) with the establishment of design advantages [31] for further use in equipment for concentrating (boiling) and drying multicomponent semi-finished products of a high degree of readiness.

Taking into account the data of the comparative analysis of the technical properties of electric heaters of the radiating type, it is possible to form an idea of the possibility and effectiveness of their use in the designs of heat and mass exchange devices for drying and concentrating polycomponent vegetable semi-finished products. The use of: tubular electric heaters, quartz lamps and ceramic electric heaters is complicated by their thermophysical parameters, in particular the working temperature of the surfaces (900…1900 °C), this requires their distance from the receiving surface when drying thermolabile raw materials. In addition, the above-mentioned radiant heaters have certain requirements for the location (horizontal for tubular quartz lamps), also according to the analysis, the heaters need a protective-focusing screen, simultaneously acting as a distributing element of heat flows. The removal of heaters from the receiving surfaces and the need to use protective focusing screens artificially increases the non-technological zones of the drying equipment with a simultaneous increase in the energy and metal capacity of the structure. In contrast to the

film-like electronic heater of the radiating type, the flexibility allows repetition of the geometric shapes of the devices under the conditions of a maximum bending radius of up to 15°, and therefore eliminates non-technological zones in conditions of uniform distribution of heat flow. The electric heater is repairable with no metal capacity, clear heating dynamics and stabilization of the temperature range in conditions of ensuring the repetition of the geometry of the working chambers. During the experimental and practical use, actions were taken to improve the basic design of the film-like electronic heater of the radiating type. In particular, according to the known structure, the heater consists of a flexible electrical insulating film (dielectric substrate) on the surface of which a resistive element with a coating thickness based on conductive nichrome paste is applied using vacuum spraying. The application of the paste was carried out in the form of sequentially connected rectangular strips, which are located perpendicular to the tires, equipped with leads for connecting to the power grid [32]. At the same time, it is equipped with additional lower and upper layers of flexible electrical insulating film, provided that the thickness of the resistive layer is: from 1.5 μm to 4.5 μm; from 5.0 μm to 8.5 μm and from 9.0 μm to 16 μm. Spraying is carried out by vacuum spraying with screen printing technology according to the given geometry of the future heating (working) surfaces. And the additional lower layer of the flexible electrical insulating film is made in the form of applied liquid thermal insulation with a low coefficient of thermal conductivity.

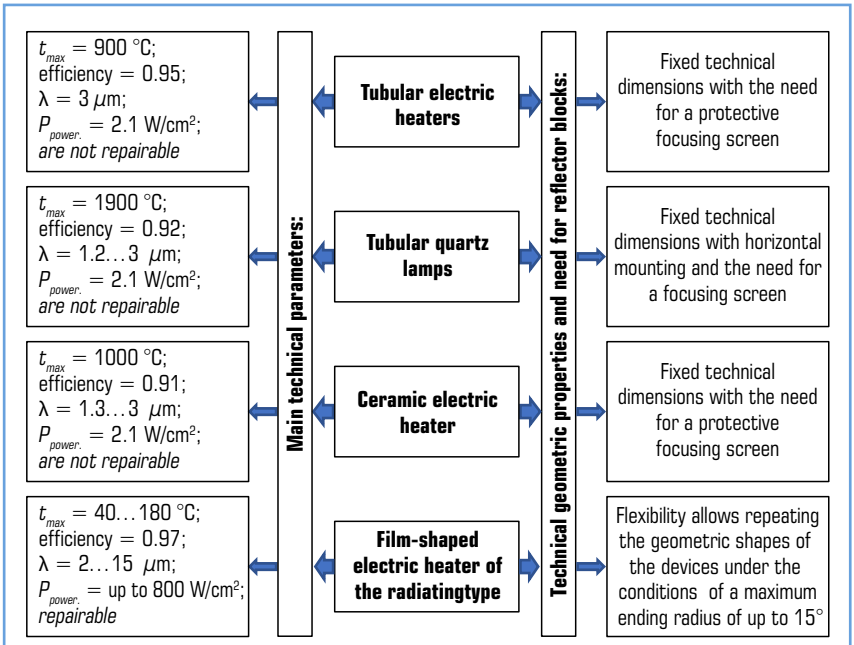


Fig. 3.6 Comparative analysis of the technical properties of radiant-type electric heaters

The schematic view of the improved film-like electronic heater of the radiating type is shown in **Fig. 3.7**.

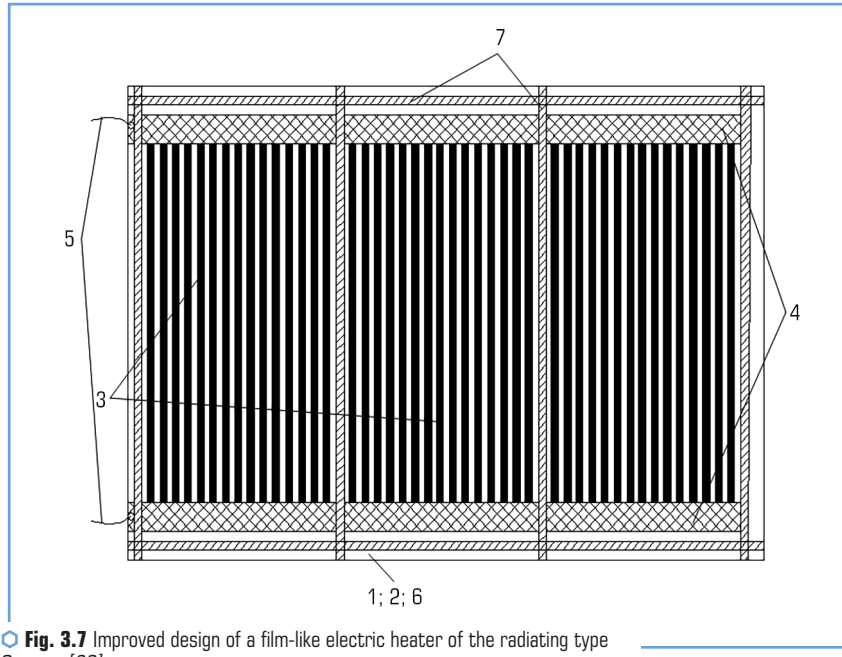


Fig. 3.7 Improved design of a film-like electric heater of the radiating type
Source: [32]

The technical result achieved when using a film-like electronic heater of the radiating type is: increase in electrical safety, reliability, hardware and technological strength, heat conservation, flexibility; fixed geometry of the heating plane, different absorption length of the radiating wave from 1.5 μm to 4.5 μm; from 5.0 μm to 8.5 μm and from 9.0 μm to 16 μm and electrical safety during operation of heating of domestic, economic and industrial premises, low-temperature heat and mass exchange equipment of the processing and food industry, in "warm floor" systems and rooms with high humidity and able to work submerged.

Thanks to the improvement, the following technical properties of the film-like electronic heater of the radiating type were achieved in terms of the maximum temperature of the working surface (40...180 °C). At the same time, the IR wavelength set from 2.0 to 15 μm with a power of up to 800 W/cm^2 and a technical efficiency factor (0.97) are optimal for heat and mass transfer processing of multicomponent vegetable semi-finished products. Confirming the effectiveness of use for drying equipment with the need for further confirmation of the effectiveness of use in heat and mass exchange equipment for the concentration of plant raw materials.

The implementation of innovative approaches consisting in the use of film-like electronic heaters of the radiating type will allow to eliminate the need for the use of intermediate coolants and technical networks in the equipment for heat-mass exchange processing of multicomponent vegetable semi-finished products. reduction of energy and metal intensity. It will create the possibility of mobility of the equipment, the simplicity of its design, its operational properties and, in general, will allow to increase the resource efficiency of the processes of concentration and drying of plant raw materials in conditions of low temperature ranges. An example of the effectiveness of improving thermal equipment for boiling multicomponent raw materials of plant origin by replacing the traditional steam heat supply with a film-like electronic heater of the radiating type is the comparative characteristics of the improved boiler compared to the basic design of MZS-320 (**Table 3.3**).

Table 3.3 Comparative characteristics of the improved boiler based on a film-like electronic heater of the radiating type in comparison with the basic design of the MZS-320 with an intermediate steam coolant

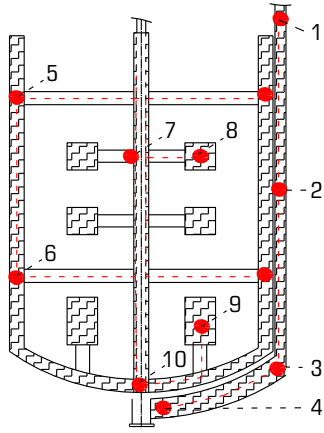
Energy losses	MZS-320	Improved steamer
Device weight	$m^*=1700$ kg	$m=m_{MZS\text{-}320}-m_{jacket}+m_{FFREHRT}=$ $=1700-620+20=1100$ kg
Specific costs	$Q_s=Q/m=1120798/1600=700$ kJ/kg	$Q_s=Q/m=651137/1600=406$ kJ/kg
Duration of processing	$\tau=Q/F\cdot k\cdot\Delta t=$ $=1191033/3.7\cdot1454\cdot91=4065$ s	$\tau=Q/F\cdot k\cdot\Delta t=$ $=1969245/4.15\cdot1454\cdot91=3586$ s
Heat exchange surface area	$F^*=3.7$ m^3	$F=F_{MZS\text{-}320}+F_{stirrer}=3.7+0.45=4.15$ m^3
Heating the device	$Q_{heat.}=m_1\cdot c_c\cdot(t_2'-t_1')+m_1\cdot c_c\cdot(t_2''-t_1'')=$ $=900\cdot0.48\times(52-25)+$ $+620\cdot0.48\cdot(142+80)=33452$ kJ	$Q_{heat.}=m_1\cdot c_c\cdot(t_2'-t_1')=$ $=900\cdot0.48\cdot(52-25)=$ $=11664$ kJ
Heating the product	$Q_{pr=}m\cdot c\cdot(t_e-t_b)=$ $=1600\cdot3.7\cdot(52-40)=2552$ kJ	$Q_{pr}=m\cdot c\cdot(t_e-t_b)=$ $=1600\cdot3.7\cdot(52-40)=72552$ kJ
Total number	$Q_{tot}=2053504$ kJ	$Q_{tot}=2009433$ kJ
Specific metal capacity of the device	$m=M/F=1700/3.7=459$ kg/m^2	$m=M/F=1100/4.15=265$ kg/m^2

**Note: calculated data are presented as an example based on previous experimental and practical results*
Source: [23, 33]

The analysis of comparative data confirms the effectiveness of using a film-like electronic heater of the radiating type in heat and mass exchange equipment when replacing intermediate coolants. Thus, a reduction in: weight and specific metal capacity of the device is ensured; duration of processing of thermolabile plant raw materials. At the same time, the peculiarities of the use of a film-like electronic heater of the radiating type make it possible to improve the design of moving devices of heat and mass exchange equipment for boiling (concentration)

multicomponent semi-finished products. This is achieved by introducing a film-like electronic heater of the radiating type into the inner space of the mixing devices and installing additional heating and contact surfaces. Such actions make it possible to artificially increase the useful surface of thermal devices and intensify the dynamics of uniform heating of raw materials with simultaneous mixing, and therefore, a reduction in the duration of the product's stay in the working space of the device is ensured.

To confirm the uniformity of the heat flow distribution in the improved boiler based on the film-like electronic heater of the radiating type under the conditions of additional heating of the unified stirring device, a fragment of the device's working chamber and thermocouple data are given (**Fig. 3.8**).



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1	140.0	7	136.0
2	135.6	8	136.5
3	136.1	9	136.2
4	136.3	10	135.8
5	135.0	11	-.-
6	135.2	12	-.-

Fig. 3.8 A fragment of the working chamber of an improved boiler based on a film-like electronic heater of the radiating type and a diagram of the placement of thermocouples with their data under the conditions of setting the electronic heater to be turned off at 140 °C
**Note: uniformity studies were carried out in laboratory conditions in real time (the error of thermocouple data is within acceptable limits)*
Source: [23]

The obtained data confirm the effectiveness of using a film-like electronic heater of the radiating type in the heat-mass exchange structures of devices for boiling (concentration).

Taking into account previously obtained experimental-practical and analytical data on the effectiveness of creating multicomponent semi-finished products of own plant origin and rheological behavior of natural raw materials during blending. There is a need for the formation of a resource-saving equipment and technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness.

3.2.1 PRACTICAL IMPLEMENTATION OF THE EQUIPMENT-TECHNOLOGICAL LINE FOR THE PRODUCTION OF VEGETABLE POLYCOMPONENT SEMI-FINISHED PRODUCTS WITH A HIGH DEGREE OF READINESS

The production of vegetable polydopamine semi-finished products of a high degree of readiness obtained from own raw materials grown according to today's eco-technologies and collected in the fields of the front-line Kharkiv region corresponds to the previously proposed method (**Fig. 3.2**). Most of the heat and mass exchange equipment used in the proposed method and equipment-technological line has a proprietary character in terms of improvement and creation of fundamentally new equipment with the main equipment-technological advantages:

– liquidation of the component of intermediate heat carriers (steam generators, steam jacket and technical networks) of heat and oil exchange equipment for the processing of vegetable raw materials;

– the use of a film-like electronic heater of the radiating type as a heat-generating element under the conditions of repeating the geometry of the working chambers to ensure a uniform distribution of the heat flow in the IR wave range $\lambda=2...16$ μm;

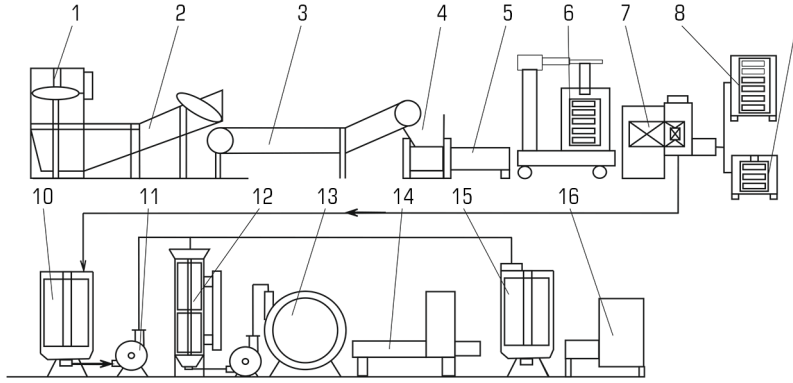
– the use of a film-like electronic heater of the radiating type to increase the useful heat exchange surface of the heat and mass exchange equipment by introducing mixing devices of the heater into the inner space and installing additional heating and contact surfaces;

– the use of a film-like electronic heater of the radiating type allows to implement low-temperature modes of processing natural polycomponent raw materials for maximum preservation of FFI and organoleptic properties;

– the use of a film-like electronic heater of the radiating type made it possible to create a fundamentally new mobile universal device for preliminary thermal operations (blanching, extraction, boiling, aging, etc.).

The general view of the equipment and technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness is shown in **Fig. 3.9**.

The equipment-technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness works according to the proposed method (**Fig. 3.2**) and can be located directly on farmland for growing natural raw materials. This became possible due to the implementation of innovative approaches in the field of improvement of the presented heat and mass exchange equipment, which is characterized by mobility, ease of operation, and resource saving in the agro-industrial sector. The practical implementation of the proposed innovative approaches in the production of polycomponent semi-finished products will allow to support the own capacities of farmland, modernization of the processing and production sectors of agro-industry. The obtained functional polycomponent semi-finished products of a high degree of readiness will allow to expand the range of food products with an increased content of FFI, predicted rheological and organoleptic properties.



1 – container dumper; 2 – conveyor washing machine; 3 – inspection roller conveyor; 4 – machine for preliminary cutting of vegetable raw materials; 5 – technological table with storage trays; 6 – universal multifunctional device; 7 – universal wiping machine; 8 – periodic IR dryer for plant extracts; 9 – extraction unit; 10 – unified reactor; 11 – gear pump; 12 – unified rotary film apparatus; 13 – thermal radiation single-drum roller dryer; 15 – unified vacuum evaporation apparatus; 14 and 16 – packing machines

Fig. 3.9 Equipment and technology line for the production of vegetable polycomponent semi-finished products with a high degree of readiness

Due to its operational and technical properties, the film-shaped electronic heater of the radiating type can be used directly in portable and mobile equipment of hotel and restaurant complexes and in the home. For example, the author's team designed a number of technological equipment for low-temperature processing of meat products in the recipe of which natural plant raw materials were added [34–38]. This, in turn, according to the equipment component, made it possible to preserve the natural properties of natural raw materials as much as possible under the conditions of minimizing intensive juice losses during frying. The surface of the meat delicacies had an optimal crust, or even without it, depending on the type of raw material and product. And from the technological side, meat products with natural vegetable raw materials and multicomponent dried semi-finished products were characterized by original organoleptic properties. In addition, the introduction of dried fractional semi-finished products into the recipes of fried meat products allows to increase the volume of raw materials and replace a certain share of recipe ingredients, in particular bread. This becomes possible because, in addition to the concentrated content of FFI, dried semi-finished products have good water-absorbing abilities, allowing them to be saturated with the liquid-fat component during the preparation of minced meat, and to release it during the frying process, preventing the product from drying out.

Taking into account the above information, it is possible to state the effectiveness of the proposed innovative approaches to the production of multicomponent semi-finished products of

a high degree of readiness with the possibility of effective use in the recipes of various food products. The obtained polycomponent semi-finished products are widely used in confectionery products, which is confirmed by a number of author's studies of the team, confirming the perspective of research in this direction. In turn, let's also support hotel and restaurant complexes to meet the needs of consumer cooperatives with the simultaneous expansion of the range of our own competitive semi-finished products of a high degree of readiness and food products based on them. Therefore, it will ensure the targeted national security of the country in the conditions of full-scale military operations and support of the world's food needs on the international market.

CONCLUSIONS

An urgent task has been formed to generalize innovative hardware and technological solutions for the production of organic plant semi-finished products (dried fractional and powdered fractions) of a high degree of readiness. The production of functional health products in the form of independent and multicomponent compositions based on plant semi-finished products of a high degree of readiness for further use in various industries during the manufacture of food products is proposed. The proposed adaptive mechanism for modeling the competitiveness of the agro-industrial sector in the conditions of taking into account the parameters of the flow of traditional micro- and macro-environments for the optimal adaptation of innovative approaches when implementing resource-saving hardware and technological solutions.

A resource-saving method for the production of multi-component pureed semi-finished products with a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, beetroot and hawthorn is presented. The hardware implementation of the resource-saving method is provided by the developed author's designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, ensuring uniformity of heat supply, stabilization of the temperature range, the possibility of using secondary heat energy. The proposed method is unified due to the implementation of the concentration process as needed in the form of a film flow (unified rotary-film apparatus), in a flow (unified tubular apparatus) and boiling in mass (unified vacuum-evaporation apparatus). Also, due to technological necessity, there is an additional technological operation of drying, which is implemented on a fundamentally new thermal radiation single-drum roller dryer.

A film-like electronic heater of the radiating type has been developed. The technical result achieved when using a film-like electronic heater of the radiating type is: increase in electrical safety, reliability, hardware and technological strength, heat conservation, flexibility; fixed geometry of the heating plane, different absorption length of the radiating wave from 1.5 μm to 4.5 μm; from 5.0 μm to 8.5 μm and from 9.0 μm to 16 μm and electrical safety during operation of heating of domestic, economic and industrial premises, low-temperature heat and mass exchange equipment

of the processing and food industry, in "warm floor" systems and rooms with high humidity and able to work submerged.

An equipment-technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness has been developed, which can be located directly on farmland for the cultivation of natural raw materials. The practical implementation of the proposed innovative approaches in the production of polycomponent semi-finished products will allow to support the own capacities of farmland, modernization of the processing and production sectors of agro-industry. The obtained functional polycomponent semi-finished products of a high degree of readiness will allow to expand the range of food products with an increased content of functionally physiological ingredients, predicted rheological and organoleptic properties. The introduction of developed semi-finished products into the recipes of various food products will reduce the need to use synthetic ingredients, replacing them with natural components.

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CHAPTER 4

CATTLE BREEDING IN UKRAINE AS ONE OF THE INDICATORS OF FOOD SECURITY

ABSTRACT

The section of the monograph analyzes statistical data on the production of agro-industrial raw materials for the period from 1990 to 2023. It has been established that during this period the ratio between the produced products of crop production and livestock production has changed significantly. The share of livestock production does not exceed 22.7 %. Animal husbandry in Ukraine, as a separate industry, is not a priority in terms of food security, and this negatively affects the consumption of animal protein by Ukrainians.

In 1990, the consumption of meat and meat products was 82.4 kg per person, which corresponded to 103 % of the recommended supply rate. Out of the total share of meat and meat products consumed in 1990, beef was predominant in the diet – 46.48 %, pork – 36.89 %, and poultry meat – 16.63 %. Over the next ten years, meat consumption decreased to only 41.1 % of the norm. From 2000 to 2020, the level of consumption of meat and meat products varied from 63.75 % to 69.25 %, the share of beef in the total mass of meat consumed decreased to 10.2 %. Beef consumption data correlates with the dynamics of changes in the cattle population.

The state of food security in Ukraine has been analyzed according to the overall value of the Global Food Security Index. According to these data, the situation with food security in the country during the war significantly worsened compared to previous years, but is not critical, in 2022, the food standards in Ukraine were provided at 70.2, the quality of consumed protein – 81.3. Unfortunately, the share of beef consumption as a source of complete protein and certain vitamins for Ukrainians is insignificant.

The reasons for the decrease in the number of livestock are analyzed. The factors that contributed to the decrease in the share of consumption of this type of meat by the population of the state have been considered. It is noted that the state of war had a negative impact on food security in Ukraine, and subsequently on the health of the nation.

KEYWORDS

Cattle breeding, food safety, beef, quality of consumed protein.

Starting from February 24, 2022, after the beginning of the full-scale invasion of the Russian Federation troops on the territory of Ukraine, hundreds of thousands of Ukrainians found themselves on the verge of starvation. The worst situation is for citizens who live in the territories where active hostilities are taking place, or who remained in cities and villages occupied by Russian troops. Under these conditions, the state cannot provide them with a sufficient amount of food, accordingly, fulfill the Constitutional obligations, therefore, it cannot guarantee food security [1].

There is still no unambiguous methodology and single indicators for assessing food security. FAO assesses the food security of countries according to internationally established criteria. However, until now, there is no consensus among scientists regarding the structure, indicators (indicators) of food security.

A team of experts from 27 academic institutions, non-governmental organizations and UN agencies from almost all continents [2] processed FAO regulatory documents, analyzed scientific articles, held more than two dozen meetings and proposed indicators for determining the objective situation of food security in the world (**Table 4.1**). To assess food security, they proposed a framework that assesses five thematic areas and consists of certain indicators. All indicators are divided into domains: diets, nutrition and health; environment and climate; means of livelihood: management: stability and sustainability (a generalized characteristic of the structure is given in **Table 4.1**). This structure, according to its developers, will allow better management of food systems within the framework of the transformation process. The authors note that the lack of food security contributes to the deterioration of the quality of the diet. After all, food security exists when "all people at any time have physical, economic and social access to sufficient, safe and nutritious food that meets their nutritional needs and nutritional preferences for an active and healthy life" [3].

Table 4.1 Thematic areas and domains of indicators

Thematic areas	Domains of indicators	Characteristics of indicators
1	2	3
Diets, nutrition and health	Diet quality	A healthy diet is essential to nutrition and health. Suboptimal diets are a direct cause of malnutrition in all its forms, including malnutrition and diet-related noncommunicable diseases (e.g., diabetes, cardiovascular disease, hypertension, stroke)
	Food safety	Food safety is a necessary condition for a healthy diet, providing free access to products. When food is insecure, diet quality also deteriorates Food security exists when "all people at all times have physical, economic and social access to sufficient, safe and nutritious food that meets their nutritional needs and nutritional preferences for an active and healthy life" [3]
	Food environments	The food environment covers the availability, adequacy and properties of food (including safety, quality, convenience and sustainability), as well as information about food and suppliers
	Policies affecting the food environment	Policies may positively or negatively impact food availability, access to products, product properties and/or product information, diets and nutrition in general

Continuation of Table 4.1

1	2	3
Environment and climate	Land use	Agriculture uses approximately 1.5 billion hectares of arable land and 3.5 billion hectares of pasture. Monitoring changes in land use is important. Land use is at the center of many ecological processes: deforestation, conversion of land to arable land will reduce greenhouse gas emissions, improve the water cycle and protect biodiversity
	Emissions of greenhouse gases	To keep global temperature rise below 1.5 °C, it is important to reduce GHG emissions from the food system, to ensure zero emissions in rural areas. Food systems account for 21–37 % of total greenhouse gas emissions, two-thirds of which come from crop and livestock production, land use and land-use change, and 63–79 % from processing, transportation and packaging
	Use of water	Fresh water scarcity limits food systems and human well-being. Approximately 2.8 billion people have problems with water resources. Food production uses up to 70–80 % of global freshwater consumption – surface and groundwater, which can lead to water scarcity [4]
	Pollution	Environmental pollution from food systems can be classified into four main categories: 1. Loss of nutrients during the production of food products and their entry into water bodies, air and/or soil (for example, nitrogen, phosphorus), which leads to soil degradation. 2. The use of new substances, in particular biocides (for example, pesticides, antibiotics), which are used in agricultural production systems. 3. Air pollution with solid particles with a diameter of less than 2.5 micrometers from organic systems (for example, residues during the combustion of organic fuel – carbon compounds, air pollution caused, to a large extent, by the introduction of manure and nitrogen fertilizers – sulfate and nitrate compounds [5]. 4. Solid waste that appears in the food chain of the creation of the product (for example, the use of non-degradable plastic, the appearance of excess animal waste that is not used as fertilizer, food waste that is sent to landfills)
	The integrity of the biosphere	The integrity of the biosphere is an indicator of the quantity and quality of natural systems and resources necessary to support nature's contribution to people's lives and stop the extinction of flora and fauna species. In food production systems, nature's ability to support food production is determined. The integrity of the biosphere is determined by indicators: 1. Indicators of the amount and distribution of semi-natural habitats embedded in agriculture track the ability of biodiversity to support food production, including through pollination of crops, regulation of pests and diseases, and support of diverse grassland ecosystems. 2. Soil condition indicators determine soil organic matter, measure the productivity of agricultural soils
Livelihoods: poverty and equity	Poverty and income	Livelihoods derived from food systems are often insecure and insufficient to support quality living standards. A disproportionate share of the world's poorest people are employed in agriculture. Wages in food systems are usually lower than the minimum wage set for other sectors
	Employment	Monitoring the quantity and quality of employment is essential to improving the equity and livelihoods of workers involved in food systems. Monitoring should cover the scale of the main employment in agriculture, food production, as well as food production in the hospitality sector. Labor productivity, which is closely related to income and wages, can reflect the quality of employment
	Social Protection	Universal social protection, i.e. guaranteed minimum access to health care, pensions, income or products for vulnerable or low-income citizens regardless of their employment status. Social protection is particularly important to support the livelihoods of many food workers
	Rights	Ensuring human rights for all is key to transforming food systems from their current state to a just one. A fundamental right in food systems is the right to food and water

Continuation of Table 4.1

1	2	3
Management	Shared vision	The shared vision addresses inclusive processes and aims to prioritize and provide guidance on desired outcomes across all thematic areas of food system transformation. Shared vision can be measured in the activities of multilateral platforms that governments create at regular intervals. Relevant stakeholders are involved in the work of the platforms. A common vision of food systems in many places on the planet is formed during dialogues between countries and independent summits (part of the UNFSS process also became a catalyst for development [6]
	Strategic planning and policy	Strategic planning and national policies should underpin a shared vision, including appropriate legal frameworks and multi-sectoral policy documents that address food systems holistically and negotiate trade-offs
	Effective implementation	Effective implementation requires alignment of strategic planning and policy with state, private sector and civil society capabilities supported by adequate human and financial resources
	Responsibility	Accountability mechanisms use monitoring and evaluation to find out whether policies are working or not, and reward (or sanction) public and private sector actors who meet (or fail to meet) commitments
Durability and stability	Impact of blows (shocks)	Assessing food system resilience requires first assessing and documenting adverse events that affect those systems. Adverse events include natural disasters, local or regional economic crises, political unrest, pandemics, pest outbreaks and protracted crises, military operations. Internationally available country-level data capture the nature, frequency, and intensity of major shocks and determine an indicator appropriate for the resilience of food systems
	Abilities for resistance	Resilience includes characteristics such as redundancy, variety, flexibility, connectivity, predictability, self-efficacy, or access to insurance or formal credit. Potential indicators of resilience include the adaptive capacity of food system participants (e.g. connectivity, social capital), social cohesion, or indicators of value chain flexibility, such as the new FAO Food Sourcing Flexibility Index, which measures diversity in different pathways to source a unit of food
	Agrobiodiversity	Agrobiodiversity plays an important role in creating the sustainability of crop, livestock, forest, fishery and aquaculture production systems. Interactions between genetic, species and ecosystem diversity at different spatial scales maintain stability in the face of increasing shocks and stresses, enable adaptation and support recovery from disturbances
	Stability of food security	One of the most important aspects of food system resilience is the ability to maintain people's food security in the face of possible shocks. Monitoring sustainability indicators (e.g. food availability, access and usability) over time is an important element of food system sustainability. The main emphasis when monitoring indicators is on their variability over time, and not on absolute levels in each report
	Sustainability index of the food system	Two complementary indices are proposed to capture different elements and relationships of sustainable food systems. The first combines all indicators in the previous thematic areas into a comprehensive, one-dimensional composite index. The second is an economical set of emblematic indicators (covering all thematic areas). Both indices can be based on well-established methodologies already used in international initiatives (e.g. Human Development Index (HDI), Global Hunger Index)

Source: [2]

Based on the analysis of the indicators of the food system proposed by scientists [2], it should be noted that food security requires a multifaceted comprehensive assessment approach and is not limited to available food products, is a necessary condition for healthy nutrition and provides access to food resources.

A new methodology based on the concept of "sustainable nutrition security" (SFS) is proposed for assessing food security [7]. This methodology allows to take into account issues of sustainability, economic, ecological and social consequences of meeting the growing demand for food, drinking water shortage and climate change. The authors of the methodology propose the definition of seven indicators, each of which is based on a combination of many indicators, for use in the characterization of sustainable nutrition results of food systems: adequacy of food nutrients; ecosystem stability; availability and sufficiency of food; socio-cultural well-being; food safety; stability; and reducing waste and losses. Dietary nutrient adequacy includes energy value of non-major foods, Shannon diversity, diversity of modified functional traits, nutrient density score, and proportion of population with adequate nutrients (the healthy eating index is specific to the United States as it was developed to measure compliance with the Dietary Guidelines of this countries [8].

The authors, for a better understanding of the impact of food systems on the environment, introduced the concept of ecosystem stability, which is broadly defined as land, water and air, as well as biological ecosystems. In addition, a food system cannot be considered sustainable if its resource base is not stable and does not have a neutral or positive impact on important ecosystem services needed outside of food systems [7].

According to the authors, the identified indicators can be used to set meaningful goals, track progress, assess the potential impact of interventions in the food system, and contribute to improving human nutrition. The characteristics of indicators, which, according to the authors, determine the sustainability of food security, are summarized in **Table 4.2**.

The analysis of **Tables 4.1, 4.2** allows to note a significant difference between the number of indicators that require control to ensure food safety. **Table 4.2** defines indicators that allow analyzing not only the provision of food to the country's population, but also social, climatic and environmental factors. According to **Table 4.2**, it is possible to identify critical situations, predict the emergence of risks and take early corrective measures at the UN level.

Table 4.2 SNS indicators and their characteristics

SNS indicators	Detailing of the indicator	Characteristics of the indicator
1	**2**	**3**
Adequacy of food nutrients	Energy of non-basic nutrition	This indicator is defined as the percentage of kilocalories available to a representative consumer from non-basic food products. Staple foods vary significantly between countries and are defined as foods that are consumed regularly and in such quantities that they account for a significant proportion of dietary energy intake. The approach is to define staple foods as all grains, roots, tubers, etc., so this figure is simply the percentage of available dietary energy (kilocalories) that does not come from these sources

Continuation of Table 4.2

1	2	3
	Shannon Diversity	The Shannon Diversity formula is used to calculate certain indicators in the numerical range from 1 to 100. The general Shannon diversity formula: $Shannon\ Diversity = -\sum is_i \ln(s_i)$, where s_i is the share (by weight) of the i-th food product in the food supply (it is necessary to take into account that if the consumption of the product drops to zero, then the contribution for this product becomes zero. This requires the application of L'Hospital's rule, since due to the uncertain nature of ln(0)). When all products are available in equal quantities, the index is ln(N), where N is the total number of products considered. The more uneven the distribution, the smaller the value of the indicator. ln(N) is normalized to a scale of 0–100 by applying a constant multiplicative factor: 100/ln(N)
	Modified functional attribute diversity	The modified functional trait diversity (MFAD) index can be used to track the Modified functional attribute diversity. MFAD – an additional measure of food supply diversity [9] gives a complete mathematical derivation that describes the diversity of functional traits as the sum of pairwise functional differences between all products of the food supply. MFAD is normalized by a constant multiplicative factor such that a value of 100 corresponds to the maximum diversity in the data set
	Assessment of nutrient density	The nutrient density of foods is usually measured as the ratio of nutrients to calories. Foods that contain more nutrients than calories are classified as nutrient dense. Nutrient balance quantifies it from different foods in a combination meal. High nutrient balance scores, scaled to a maximum value of 100, indicate that a particular food combination provided both nutrient adequacy and nutrient balance [10]
	Proportion of the population with sufficient nutrients	Diet quality indicators depend on statistical information collected for different categories of people. A method for estimating the prevalence of adequate nutrient intake in a population [11] is defined as the percentage of the population consuming more than the estimated average requirement. The population distribution of intake is constructed for each nutrient from the mean value using the coefficient of variation. The population distribution of intake can be defined as a simple average of all population shares in such nutrients
Ecosystem stability	Ecosystem status	Ecosystem status was quantified by the Yale University Center for Environmental Law and Policy and Columbia University Center for the International Earth Sciences Information Network using the Environmental Performance Index (EPI) [12]. The EPI assesses how well countries are addressing priority environmental issues in two broad policy areas: protecting human health from the harmful effects of the environment and protecting ecosystems. Ecosystem status was calculated as the simple mean of the following indicators: water resources, agriculture, forests, fisheries and biodiversity/habitat
	Emissions of greenhouse gases (GHG) per capita	Food system activities include land transformation, food production, storage, transportation, processing, retailing, preparation and post-consumer waste – the latter of which results in significant CH_4 (methane) emissions. The largest sources of emissions in agriculture are direct land-use change (LDU), fertilizer production, N_2O emissions from fertilizer-based soil, and methane (rice and ruminants). National greenhouse gas inventories and emission reduction targets are monitored through the United Nations Framework Convention on Climate Change (UNFCCC). Accordingly, the GHG indicator is defined as the annual greenhouse gas emissions of the food system per capita (kg CO_2e per person per year), converted on a scale of 0–100 using the equation (note). It includes methane emissions associated with food waste

Continuation of Table 4.2

1	2	3
	Clean intake of fresh water per capita	Much of the water use in food systems is related to crop irrigation, but there are other (generally smaller) uses of water in food value chains [13]. LCA modeling allows the calculation of water use associated with food systems [14]. The proposed indicator is defined as the annual net withdrawal of fresh water per capita by the food system (m^3 of fresh water per person per year), regardless of where this withdrawal is made. "Net withdrawal" is water consumption (that is, water used by food systems and no longer available to other users). It is converted to a 0–100 scale using the equation*
	Non-renewable energy consumption per capita	The fuel is used for the production of fertilizers, increasing the mechanization of agriculture and improving the food industry, and for transportation. The metric is defined as the annual non-renewable energy consumption per capita by the food system (MJ per person per year) and is converted to a scale of 0–100 using the equation*
	Land use per capita	FAO and other organizations monitor land use on the planet to meet growing demand without the need to bring new land into production
Availability and food availability	Availability of food	This indicator is defined as food system land use per capita (m^2 per person per year), regardless of where the land use occurs and what type it is (e.g., grazing pastures are included). It is converted to a 0–100 scale using the equation*. A generally accepted measure of food availability, which is already widely used among economists, is the share of average annual income that goes to food [15]. As incomes rise, the share spent on food decreases. Another set of metrics that have been used are calories and nutrients per unit cost [16]. Definition of this indicator: the share (in percent) of household spending on goods other than food. The advantage of such a definition is that it can be easily calculated for various future socio-economic and climate scenarios using an integrated model such as IMPACT [17]
	GFSI food availability	The GFSI Food Availability indicator measures factors that affect food supply and the ease of physical access to food. It examines how structural aspects determine a country's ability to produce and distribute food, and explores elements that may create bottlenecks or risks to sustainable availability. The GFSI examines several aspects of food availability to determine the ease of access in each country and is calculated by the Economist Intelligence Unit (EIU) using various data sources, including FAO, OECD, World Bank and World Food. The GFSI Food Availability score is calculated on a scale of 0–100, so it is used directly as an indicator
	Poverty index	The Global Food Safety Initiative (GFSI) uses a factor of the proportion of each country's population living below the poverty line, which is defined as 1.90 USD per day According to GFSI, the authors chose [7] a threshold value of 1.90 USD for the day and converted the indicator into the desired format, simply expressing it as a percentage exceeding the threshold value of 1.90 USD per day
	Income equality	The most widely used measure of income inequality is the Gini coefficient, G, which has a value of 0 in the case of complete income equality and one (1 or 100) in the case of all income received by one person in a country [7]. Thus, the indicator is converted to the desired format using 100-G, higher values indicating higher income equality

Continuation of Table 4.2

1	2	3
Socio-cultural well-being	Gender equality	The Global Gender Gap Index (GGGI) was developed by the World Economic Forum as a basis for assessing the magnitude of gender inequality [18], and was chosen as the basis for this indicator. GGGI assessed 140 countries using a methodology that focuses on identifying gender gaps in access to resources. This makes it possible to compare countries regardless of their level of economic development. The four indicators used to determine the overall GGGI are economic participation and opportunity, education, health and survival rates, and political empowerment. The GGGI is scored by the World Economic Forum on a scale of 0–1 and is simply multiplied by 100 to use as an indicator
	Scales of child labor	The child labor indicator is calculated as the percentage of children aged 5–17 (defined by the ILO International Labor Organization) in a country who are employed in the food system. As with environmental scores, this is converted to a score of 0–100 using the equation*
	Respect for community rights	The World Resources Institute (WRI) quantified the degree of community rights in relations with corporate buyers by determining the Environmental Democracy Index (EDI) [19]. The index is based on the presence of adequate legal protection of community rights in the form of national laws. EDI [20] is defined by scale values from 0 to 2.39, so multiplying by a factor of 40 results in results on the desired scale of 0–100
	Animal health and welfare	To determine the health and welfare of animals in agricultural settings, the Animal Protection Index (API) was introduced, which ranks countries according to their commitment to animal protection [21], and can be used to quantify this indicator. The API rating scheme assigns letter grades to countries in the ranking, ranging from a high 'A' to a low 'G'. This converts to a numerical scale of 0–100 as follows: A=95, B=85, C=75, D=65, E=55, F=45, G=35
Stability	ND-GAIN country index	The University of Notre Dame Global Adaptation Index (ND-GAIN Country Index) was introduced to summarize a country's vulnerability to climate change and other global challenges, combined with its readiness to improve resilience for adaptation. The ND-GAIN assessment consists of a vulnerability assessment and a readiness assessment. Vulnerability measures a country's vulnerability, sensitivity and ability to adapt to the negative effects of climate change. Readiness measures a country's ability to attract investments and transform them into adaptation actions, taking into account economic, governance and social readiness. The authors [7] note that not all indicators are the basis of ND-GAIN, that it is advisable to include additional factors related to drought and coastal flood preparedness. ND-GAIN represents the total value indicated on a scale of 0–100, so it is directly used as an indicator
	Variety of food production	The diversity of food production at the national level is recommended to be calculated using Shannon's formula. As s_i, it is recommended to use shares of agricultural production [9], based on the weight of each food product produced in the country. A constant multiplicative factor is used to scale the indicator to a scale of 0–100: $100/\ln(N)$, where N is again the total number of food products considered
Food safety	Consequences of foodborne diseases	WHO has developed models to assess the consequences of foodborne diseases where current data are not available [22]. The GBFI (Global Burden of Foodborne Illnesses) data are the best estimates of foodborne illnesses and are used to estimate the Global Burden of Foodborne Illnesses (based on regional significance). GBFIs are converted to a scale of 0–100 using the equation*

Continuation of Table 4.2

1	2	3
	GFSI food safety	Each year, the Global Food Security Index (GFSI) [23] provides an additional indicator of food security. It has three components: 1) whether the country has a regulatory authority to ensure food safety; 2) percentage of population with access to potable water; 3) the presence of a formal food sector. The presence of a regulatory body to ensure food safety is a qualitative indicator of 0–1 (0=no, 1=yes) assessed by EIU analysts. The percentage of the population with access to drinking water is a quantitative estimate based on World Bank data that estimates the percentage of the population with access to drinking water from drinking water sources, domestic connections, public drains, boreholes, protected dug wells, protected springs and rain water The presence of the formal food sector is qualitatively assessed by EIU analysts on a scale of 0–2 (0=minimal presence; 1=moderate presence; 2=extensive presence). The overall GFSI food safety score is calculated from these three indicators and reported on a scale (0–100) that can be used directly as an indicator
Reduction of waste and losses	–	Calculating an indicator to quantify waste and loss is simply to express as a percentage the part of food produced that is not lost (before consumption) and not wasted (after production)

Source: [7]

**Note: the equation for obtaining a score of 0–100: Metric Indicators* $= 100 \cdot \exp \ln(0.5) \cdot (F_i / F_{50}]$, *where F_i is the factor (e.g. GHG emissions or land use) for the i-th unit (e.g. country) considered; F_{50} is the median (50th percentile) of the full range of values for this factor for all study units measured during a specific base year.*

Using this equation has the desired characteristics, giving a score of 100 for the hypothetical case of no emissions/use, a score of 50 for the median performance, asymptotically approaching a score of 0 with increasing emissions/use, and resulting in a normal distribution score if the underlying data is log-normal distribution [7]

Comparison of key indicators that determine the stability of food security in the world and Ukraine differ significantly. In Ukrainian legislation, this issue is narrowly limited only to access to food products. Although, in the conditions of war, even this indicator cannot always be guaranteed by the state.

Even before the full-scale war in Ukraine, as of 2021, summarized world reports indicated that 9.9 % of the world's population (768 million people) do not have access to enough calories to meet their needs; about 2.37 billion people are moderately or severely food insecure; and 3 billion people cannot afford a healthy diet [24]. If to compare the years 2021 and 2022, then in general, acute food insecurity in the world has decreased from 11.7 % in 2021 to 11.3 % in 2022, which indicates a reduction of 27 million people who are hungry. However, the number of people living in conditions of lack of food security is 900 million, which is 180 million more than in 2019. According to forecasts [25], up to 600 million people will be chronically hungry in 2030. A positive trend in reducing the number of hungry people is predicted

for the countries of Latin America and the Caribbean, and a significant increase in hunger is predicted in Africa by 2030.

4.1 LITERATURE REVIEW AND PROBLEM STATEMENT

In order to implement the National Security Strategy of Ukraine, approved by the Decree of the President of Ukraine dated September 14, 2020 No. 392/2020 and the Sustainable Development Goals of Ukraine for the period until 2030, approved by the Decree of the President of Ukraine dated September 30, 2019 No. 722/2019 [1], according by order of the Cabinet of Ministers of Ukraine in 2020, the project "Food security strategies for the period until 2030" was developed [26]. The project has a definition – "food security is the security of a person, which consists in the fact that a person at any time has physical and economic access to a sufficient amount of safe food products that meet its nutritional needs for an active and healthy lifestyle". Therefore, food security must be ensured by the state for all sections of the population, in particular, "risk groups – the most vulnerable sections of the population, persons whose incomes belong to the lower quintile group".

The level of ensuring food security is determined by "food security indicators – quantitative and qualitative characteristics of the state, dynamics and prospects of the physical and economic availability of food products for all social and demographic groups of the population, the level and structure of their consumption, the quality and safety of food, the sustainability and degree of independence of the domestic food market" and "food safety criteria – the limit (threshold) value of the indicator, which is the limit beyond which a food threat occurs". That is, food security is a complex system of measures and actions on the part of the state, which guarantees the satisfaction of the needs for the necessary food products to ensure the full functioning of the human body. Important in the general list are products of animal origin that provide a person with complete protein, which includes beef and its products.

Scientists in the field of economics and the agro-industrial sector paid attention to the study of food security: V. Hrynyshyn, Y. Batyr, Z. Zhyvko, N. Danylenko, M. Stadnyk, S. Oliferuk, M. Fleichuk, A. Mostova, E. Starychenko, O. Varaksina, V. Adamyk, L. Chernobai, V. Shyshlyuk and others. Common to all scientific works is an emphasis on the quantitative factor, the regulation of relations in the agro-industrial sphere [27]. However, insufficient attention is paid to an integrated approach to food security issues. For example, the issues of ensuring the quality and safety of food products by processing enterprises are resolved according to the requirements of regulatory and technical documentation, and attention is not focused on the problem of food and biological value of products, although it should be a priority.

It is possible to ensure a balanced diet at the expense of products from vegetable and animal raw materials. Vegetable raw materials are, to a large extent, a source of carbohydrates, fats of different chemical composition and structure, vitamins, micro- and macroelements. Raw materials

of animal origin: beef, pork, chicken, dairy products, eggs, etc., mainly provide the human body with proteins and fats, in particular, essential amino acids, vitamin-like fatty acids. The presence of all the necessary nutrients in the daily diet determines the completeness of nutrition.

Fish provides more than 4.5 billion people with at least 15 % of their average per capita intake of animal protein. The unique nutritional properties of fish also make it essential to the health of billions of consumers in both developed and developing countries.

In 2012, the Committee on World Food Security (CFS) took an important step in the right direction by requesting the High-Level Panel on Food Security (HLPE) to conduct an in-depth study on the role of sustainable fisheries and aquaculture for the FSN. The 2014 HLPE report [28] presents the strongest argument for including fish in the food system. According to recent estimates, for example, in 2009, fish accounted for 17 % of animal protein consumption by the global population and 6.5 % of all protein consumed [29]. According to estimates [30], for example, fisheries and aquaculture provide 3.0 billion people with almost 20 % medieval per capita consumption of animal protein, and another 1.3 billion people with about 15 % per capita consumption. It is noted that significant consumption of fish and seafood is observed in island countries.

Analysis of the possibilities of food supply with products containing complete protein of animal origin showed significant problems with solving this issue on a global scale. This issue is becoming an even bigger problem in Ukraine. Therefore, providing the population of Ukraine with the necessary products that are full-fledged for human life and health should be a priority in the state policy.

4.2 THE AIM AND OBJECTIVES OF RESEARCH

Therefore, in order to implement the state policy in the field of food security, it is necessary to pay attention to providing the population of Ukraine with food products with high nutritional and biological value, which includes beef and its products.

In accordance with the stated problem, the purpose of the article is to analyze the state of cattle breeding in Ukraine over the past 30 years and determine the possible reasons that affect the degree of providing the population with meat and meat products, in particular, beef and its products, in the context of the country's food security. In accordance with the goal, the following tasks were formulated:

– to determine the trend of changes in the state of cattle breeding in Ukraine over the past 30 years and its impact on the consumption of beef by citizens of Ukraine;

– to determine the impact of the worsening situation in cattle breeding on the quality of nutrition of Ukrainians according to the Global Food Security Index, in particular, food security;

– to establish the reasons that affect the decrease in the share of beef consumption by Ukrainians.

To realize the aim, the article uses the following research methods: general scientific methods of analysis, comparison, systematization, and generalization.

4.3 RESEARCH RESULTS

The range of products that provide optimal nutrition for different segments of the population, taking into account physiological needs, activity, and age, is large. There are a number of basic food products, the main types of raw materials for which are plant and animal products. A study of the dynamics of changes in the state of Ukraine's economy, conducted by H. Morozova [31], made it possible to establish that the specific weight of plant and animal products in gross agricultural products has changed over the past 30 years. According to the author's analysis, in 1990 the specific weight of crop production was 51.5 % (3 % more than livestock production), in 2000 it was 61.5 % (23 % more than livestock production), and already in 2011 it was 69.5 %, i.e. the production of plant products is 2.3 times higher than the production of livestock products. In 2020 [32], the ratio of the specific weight of plant and animal husbandry in the total volume of agricultural products in Ukraine was already 77.3 and 22.7 %, i.e., the production of plant products for Ukraine has become the dominant direction in agriculture. The gradual decrease in the production of livestock products contributed to the increase in prices for it, respectively, to a decrease in its share in the general diet of the average Ukrainian. This conclusion is confirmed by the data in **Table 4.3**.

Animal husbandry in Ukraine, as a separate industry, has ceased to be a priority in food security. Such a redistribution in the production of agricultural products is reflected in the balanced nutrition of the population.

In recent years, the share of vegetarians has been increasing. However, the vast majority of the population of Ukraine traditionally satisfies the physiological need for protein with products of animal origin. A decrease in the proportion of complete protein in the diet can lead to a deterioration in the health of the population, life expectancy, etc.

According to the data of the Statistical Collections of Ukraine in figures [33] for the period from 2000 to 2021, there was a tendency to increase the mass of products of animal origin in the diet of the population of Ukraine, with some changes (**Table 4.3**). Minimum consumption values of meat, fish, and eggs, according to the statistical collection, in 2000. In the following years, there is growth with minor changes. The consumption of milk and dairy products has changed little over twenty years. However, when compared with the recommended norms, the consumption of protein products does not meet the recommendations. In 2000, meat consumption was 41 % of the norm, fish – 42 %, milk – 52.4 %, eggs – 57.2 % (**Fig. 4.1**). These shares testify to the negative impact of the economic situation in the country, on nutrition, and, accordingly, the degree of satisfaction with the protein component of the diet of the average Ukrainian.

The next 10 years, during 2000–2010, the growth in the level of welfare of the population, the development of the agro-industrial sector, contributed to the increase in the degree of balance of the diet with a protein component. In 2010, the share of meat consumption was 65 % of the norm, fish – 72.5 %, milk – 54.3 %, eggs – 100.0 %.

The economic situation that developed in Ukraine after 2014 had a negative impact on the purchasing power of the population, the consumption of animal products partially decreased (**Table 4.3**, **Fig. 4.1**). In the period from 2015 to 2020, there is a positive trend in the growth of consumption of meat and meat products. During these five years, consumption of meat and meat products increased by 3.6 %, fish – by 19.0 %. At the same time, milk consumption varied from 2.0 to 3.1 %, eggs – from 2.0 to 5.1 % (**Table 4.3**).

Table 4.3 Consumption of food products from raw materials of animal origin

The name of the food category	Consumption rate, kg/year [34]	Year									
		2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Meat, meat products	80	32.8	39.1	52.0	50.9	51.4	51.7	52.8	53.6	53.8	53.0
Fish, fish products	20	8.4	14.4	14.5	8.6	9.6	10.8	11.8	12.5	12.4	13.2
Milk, milk products, in terms of milk	380	199.1	225.6	206.4	209.9	209.5	200.0	197.7	200.5	201.9	201.5
Eggs, pc	290	166	238	290	280	267	273	275	282	278	272

Source: [35]

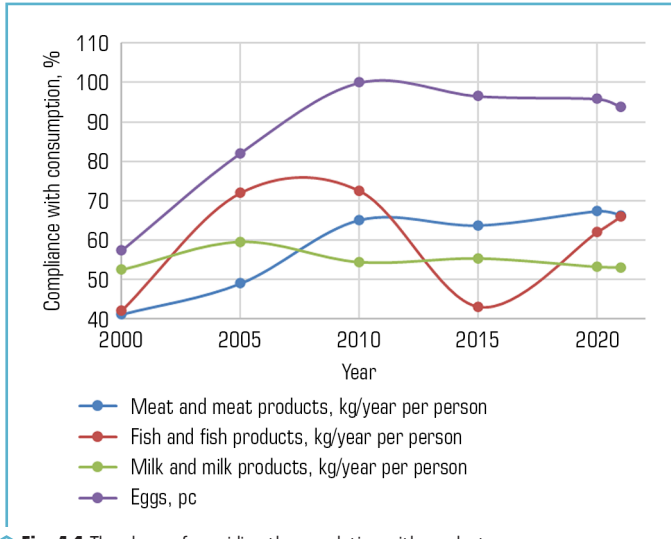

Fig. 4.1 The share of providing the population with products of animal origin, % of the norm

According to the data analysis (**Table 4.3**), for the time period from 2010 to 2020, there is no clear positive trend towards an increase in the share of consumption of food products of animal origin. The main share of protein in the diet is provided by eggs – more than 90 % of the recommended norm, meat – from 60 to 70 %, fish – from 40 to 70 %. Ukrainians consume the least milk and dairy products, the share of consumption of the recommended norm does not exceed 60 %. This share, with minor changes, can be a testimony to the taste preferences of Ukrainians and does not depend on the economic situation in the country.

From the data of **Table 4.3** and **Fig. 4.1**, meat and meat products deserve considerable attention. After all, different types of meat differ in their chemical composition, nutritional and biological value. At the same time, the total share of consumed meat does not provide an opportunity to determine the level of well-being of the population. This is reflected in the data of **Table 4.4** (the difference in the total weight of meat – the data of **Tables 4.3, 4.4** is explained by the fact that in **Table 4.4** the weight of meat of other types of animals, not industrially reared and processed) is taken into account.

Table 4.4 Meat consumption in Ukraine by main types

Meat consumption by species, kg/person per year [36]	Years							
	1990	2000	2010	2013	2015	2018	2020	2021 [37]
Beef	38.3	15.3	9.8	9.2	8.2	8.5	7.9	5.3
Pork	30.4	13.7	18.0	21.8	18.1	16.6	19.5	15.5
Chicken, duck, turkey	13.7	3.9	23.2	24.4	24.2	29.8	25.6	24.4
Total*	82.4	32.9	51.0	55.4	50.5	54.9	53.0	52.0 (including 6.8 kg of other types of meat, offal, animal fat)

Note: the data in **Table 4.4 for the final amount of meat consumption differ slightly from the data in **Table 4.3** due to unaccounted statistical summaries and values taken from different information sources*

A significant redistribution between types of meat is immediately visible from the data of **Table 4.4**. In 1990, the consumption of meat and meat products was 82.4 kg per person, which corresponded to 103 % of the recommended supply rate. The predominant part of the diet was beef – 46.48 %, a significant share of pork – 36.89 %, and 16.63 % poultry meat. Over the next ten years, meat consumption decreased to 32.9 kg per person, which was only 41.1 % of the recommended norm. Accordingly, there was a decrease in the mass of consumption by various types. However, in 2000, beef was predominant in the diet of Ukrainians and accounted for 46.5 %. In the next twenty years, the share of beef in the total mass of meat consumed decreased to 10.2 %. The share of pork in the total diet varied from 41.6 % in 2000 to 29.8 % in 2021.

The discrepancy between the needs, norms and actual consumption of various types of food products is shown in the work [38]. The author noted that the level of self-sufficiency in Ukraine

for most food products, for example, in 2017, exceeded 100 %. A number of food products produced by the processing industry, in particular of animal origin, exceeded the need for domestic consumption, for example: meat and meat products – 105.4 %, eggs – 114 %, milk – 103.6 %.

However, the production of food products and the level of consumption (**Fig. 4.1**) in this period of time do not coincide. The industry is able to provide the population's physiological needs in products of animal origin, but the population consumes only eggs, at the normal level, meat, meat products, fish, milk and dairy products, according to the level of provision from 40 to 70 % (**Fig. 4.1**). The reasons can be different: the food system – rejection of products of animal origin (veganism), family traditions, lack of material resources for these products, unaccounted for products from one's own household. Of the above, the products obtained in one's own household are of significant importance. After all, these are poultry, rabbits, and small cattle, fish caught in a pond or in a river. A general unofficial survey among applicants of the Mykolaiv National Agrarian University showed that the presence of relatives in the countryside allows providing 1–2 families in the city with agricultural products by 50–70 %.

At the international level, a methodology for assessing food security in the country based on a general index was created. The general index of food security in the country is estimated by the Global Food Security Index (GFSI) and is based on a dynamic benchmarking model and consists of 58 qualitative and quantitative drivers of food security in 113 countries, which are grouped into four main criteria: food availability, sufficiency (availability), quality and security, natural resources and sustainability. food security. Developed by Economist with support from Corteva Agriscience. The index is based on a dynamic comparative analysis of a model built from 58 qualitative and quantitative factors of food security [39].

In general terms, the Global Food Security Index for Ukraine in the same 2017 was 54.1 for 63rd place in the overall ranking out of 113 countries of the world [40]. By 2021, this indicator increased to 62.0 and Ukraine rose in the overall rating to 58th place [39] The war in 2022 worsened the situation in the state in all directions, this led to a decrease in the overall value of the Global Food Security Index for Ukraine to 57.9, the country found itself on 71st place in the ranking between Paraguay and Myanmar [41]. According to the Global Food Security Index 2022. Ukraine [42] in 2022, the values of each of the analyzed indices were: accessibility – 66.6; sufficiency – 48.1; quality and safety – 71.3; stability and adaptation – 43.5. In addition to the indices of the main groups, each of the 113 analyzed countries is evaluated according to the following indicators: income level – income below the average; prevalence of malnutrition – 2.8 %; the percentage of children with growth retardation – 15.9 %; percentage of underweight children – 4.1 %; prevalence of obesity – 26.1 %; human development index – 0.78. Accordingly, it is impossible to draw an unequivocal conclusion about the lack of food products in Ukraine last year. Due to the military aggression, the loss of a large part of the manufactured products, the disruption of logistics in the supply of products, the sufficiency (availability) has decreased, one might add, the uninterrupted supply. Of all the complex criteria, it is "quality and safety" that measure the variety and nutrition of average rations, as well as the safety of food products and

testify to the level of satisfaction with this or that group of products. In 2022, the quality of food was characterized by an index with a rating of 71.3. According to individual components of this criterion, nutrition standards (source: FAO) in Ukraine were provided at 70.2, the quality of consumed protein – 81.3 (source: calculation of EI based on data of FAO, WHO and the nutrient database of the US Department of Agriculture (USDA)). The amount of protein is measured using the (PDCAAS) amino acid scale methodology with protein digestibility correction. The presence of nine essential amino acids in the average national diet is estimated based on input data: amino acid profile, protein digestibility value, and average amount (in grams) consumed of each food product. On the basis of this information [42] and the initial data for calculating the quality of consumed protein, it is possible to conclude that in the average annual diet of Ukrainians, the protein is mainly animal protein, since it is the protein of animal origin that has the most balanced amino acid composition [41].

Confirmation of the results of calculations of the overall value of the Global Index of Food Security in Ukraine were surveys of higher education students of the Mykolaiv National Agrarian University regarding their diet in May 2022. An analysis of the diet of young people aged 19–20 who lived in the South of Ukraine showed that the caloric content of the diet was insufficient, and it was provided with proteins and fats. Proteins from poultry, pork, river fish and eggs prevailed in the diet, and beef proteins were almost absent. Residents of rural areas had the opportunity to consume a significant proportion of proteins from dairy products. The increase in the prices of cereal products, fruits and vegetables reduced the consumption of functional carbohydrates and vitamins, which worsened the well-being of students. Significant differences in students' diets were explained by the place of stay. Some of them were in the zone of active hostilities, some in the countryside, in a more peaceful place. The result of these observations showed the significant impact of the war on their nutrition and the inferiority of the rations in general.

The previous analysis refers to peacetime. As it is possible to see, before the war, the supply of meat products changed according to the demands of the population. Even the economic crisis related to Covid-19 did not have a significant impact on the level of consumption of livestock products by Ukrainians. Changes in consumption were caused by factors directly responsible for the agro-industrial sector, the food industry, and government policy in the field of food security. The meat processing branch of the food industry is responsible for the nutritional and biological value of meat products. The production of such products requires high-quality raw materials, in particular, beef, which is the basis of a large assortment of meat products.

The quality of beef is affected by everyday factors and processing conditions at meat processing plants. Among the everyday factors that significantly affect the quality of meat, the following can be distinguished: the breed of cattle and its genetic potential; the conditions and technology of cattle breeding, including the intensity of fattening of young cattle and the balance of rations; the state of health of animals and the timeliness of carrying out a complex of veterinary measures. The genetic potential of livestock, which is not revealed in the case of an inferior fattening diet and maintenance, is of great importance. Production factors during processing have

no less influence on the quality of beef: conditions of pre-slaughter aging, slaughter, methods of cold processing.

The efficiency of raising livestock, which is further processed, depends on the technology of keeping, the main goal of which is the maximum satisfaction of all the physiological needs of animals [43]. There are a number of general rules for conducting agricultural activities related to cattle breeding. However, the effectiveness of this activity depends on subjective factors. The technology of raising animals depends on the size of the farm, the soil and climatic characteristics of the region, the availability of its own fodder base and workforce and specialized specialists, etc. The method of keeping animals tethered or untethered determines the level of mechanization. A high concentration of livestock allows mechanization of certain production processes: distribution of fodder, milking of cows, removal of manure. At the same time, the high level of mechanization of the production process contributes to the creation of an additional noise effect, vibration, gassiness of the premises, which negatively affects the emotional state of animals, which must be taken into account when organizing the technological cycle of livestock breeding.

In Ukraine, mainly dairy and meat-milk breeds of cattle are raised. Only some agricultural companies have beef cattle, the total share of which is negligible. According to the Ukrainian Association for the Development of Animal Husbandry and Technologies, as of August 1, 2021 [44] there were 54,205,000 head of meat cattle in the farms of the legal sector, and 19,283,000 in the farms of individuals. At the same time, according to the data of the State Statistics Service of Ukraine [45], the total number of cattle in Ukraine was estimated at almost 3219.1 thousand heads, including cows – in 1662.1 thousand heads. So, the share of beef cattle was 2.28 % of the total number. This amount of livestock is not enough to talk about the industrial scale of cultivation for the processing industry. In the leading countries of the world, 52–53 % of raw materials from cattle of meat breeds are used for the production of meat products. And in countries such as Canada, the USA, Great Britain and France, this percentage is much higher [46].

According to the analysis of H. Morozova [31], the revival of cattle breeding for farmers has become a series of problems associated with significant capital investments – the construction of new livestock farms or the reconstruction of old buildings, the restoration of cultural pastures. The main problem for the development of the industry has become the low productivity potential of the existing herd of cows, for the improvement of which it is necessary to drastically improve the selection and breeding work.

At the same time, along with the decline of cattle breeding in the state, the active development of poultry farming began. The increase in the production and consumption of chicken (**Table 4.4**) contributed to the expansion of the range of meat products and provided economic stability to meat processing enterprises.

The appearance of cheap chicken did not contribute to the improvement of the situation in cattle breeding. Animal husbandry became unprofitable and agricultural enterprises began to reduce livestock. According to the analysis of S. Bohdanko [47], in 1990, 85.6 % of all cattle herds belonged to agricultural enterprises, in 1995 this share was already 78 %, and the number of

herds decreased from 21,083 million heads to 1,511 million heads. However, in the first decades of Ukrainian independence, the number of cattle in households not only did not decrease, but even increased from 14.4 % to 46.5 %. Thus, in 1990, the number of livestock in households was 3. Subsequently, this trend remained (**Table 4.5**). Keeping livestock in households is focused on milk production. For rural residents, dairy animals are a source of small additional income. Owners of 1–2 cows are in no hurry to change the technology of raising animals. Accordingly, the cost of raising and keeping livestock was prohibitively high, and therefore, the cost of 1 kg of beef was and is high. This could not but affect its consumption by citizens of Ukraine.

According to the analysis of O. Kukhar, the situation with the cultivation of cattle in the conditions of agricultural enterprises continued to deteriorate in the next decade [48]. This could not but affect the volume of meat produced. In 1990, the production of beef and veal amounted to 1808 thousand tons, in 2011 it decreased to 97 thousand tons. Households produced 302 thousand tons of beef in 2011 against 177 thousand tons in 1990. Such changes affected on beef consumption by the population. Poultry became predominant in the diet.

Breeding and, in some cases, cattle processing in households has had a significant impact on meat processing enterprises. During the analyzed period, large, powerful plants and factories ceased to function, and instead small sausage shops were opened, the production activity of which was connected with the regional supply of meat products to the population. The emergence of low-power enterprises had advantages and disadvantages. On the one hand, the enterprise quickly responded to consumer demand, their activity did not require the supply of large batches of raw materials, on the other hand, there was a problem with the quality of products, their nutritional value. The lack of continuous laboratory control over the quality of raw materials and finished products could not guarantee the safety of these products for Ukrainians.

In recent decades, before the military aggression of the Russian Federation, there was a tendency to decrease the number of cattle in Ukraine. Analysts of the agro-industrial sector predicted a further decline in beef production and an increase in the price of meat [49]. The main reasons, according to experts, were: "disparity in prices for agricultural and industrial products; increase in the cost of fodder; the inability of the majority of domestic producers to apply the latest technologies for keeping and feeding animals, since the enterprises do not have free funds for this; destruction of large highly specialized farms for growing and fattening young cattle [36]; low solvency of the country's population, which mostly buys cheaper types of meat (about 48 % of all meat consumed in Ukraine is poultry meat, pork – 35 %, beef – 14 % [37]); an increase in the amount of foreign-made raw materials on the domestic market, the price and quality of which is significantly lower; reducing the amount of state support". This forecast is confirmed by the statistical data shown in **Table 4.5**.

Analysis of the **Table 4.3** shows a rapid decrease in livestock in Ukraine during the first 15 years after the collapse of the Soviet Union. At the beginning of 2022, the share of livestock is 1/10 of the number in 1990. By region, the livestock is distributed as follows [50]: more than 50 % of all cattle are kept in 9 regions – Vinnytsia (8.4 % of the total), Poltava (6.6 %),

Khmelnytskyi (6.3 %), Chernihiv (5.3 %), Lviv (5.3 %), Kharkiv (5.3 %), Zhytomyr (5.0 %), Cherkasy (4.8 %) and Odesa (4.6 %). The main producers of beef and veal, as in the previous decade, were and are private households. Their share accounts for 73.6 % of its total volume in the slaughter mass. If to talk about breeding stock, then according to the results of 2021 [51], Poltava region became the leader in terms of the number of cattle and cows in agricultural enterprises, and fourth in terms of pig stock. It is in the Poltava region that 70 agricultural enterprises operate, which have the status of a subject of tribal business in animal husbandry. Poltava region is the leader among the regions of Ukraine in terms of the number of breeding cattle – 32.079 thousand heads or 10.2 % of the total breeding livestock in Ukraine. However, for an agrarian country, such a number of breeding cattle is tiny.

Table 4.5 Dynamics of changes in the cattle population according to the State Statistics Service of Ukraine

Year	Cattle number as of 01 January (* of 01 February [52]), thsd. Heads [53]		Current year/up to 1990, %
1990	25194.8*		100.0
1995	19624.3*		77.9
2000	10626.5*		42.2
2005	6966.9*		27.7
2010	4826.7*	1627.1 (Enterprises) 3199.6 (Households)	19.2
2015	3983.9	1314.1 (Enterprises) 2669.8 (Households)	15.8
2019	3332.9	1138.1 (Enterprises) 2194.8 (Households)	13.2
2020	3117.7	1049.1 (Enterprises) 2068.6 (Households)	12.4
2021	2874	1008.4 (Enterprises) 1865.6 (Households)	11.4
2022	2689.4	998.5 (Enterprises) 1690.9 (Households)	10.7
2023*	2644.0 [54]	1003,4 (Enterprises) 1640,6 (Households)	10.49
2024*	2307.1 [54]	942.1 (Enterprises) 1365,0 (Households)	9.16

**Note: the information was formed on the basis of reports actually submitted by enterprises (the level of reporting was 88 %) and additional assessments of indicators. Data can be refined [54]*

4.4 DISCUSSION OF RESULTS

The general dynamics of changes in the number of cattle (**Table 4.5**) logically explains the decline in the production of chilled beef and veal (carcasses, half-carcasses and quarters) in Ukraine. During the analyzed period, production volumes decreased unevenly, in 2018 this decrease was minimal, and in 2019 it reached 8 %. In 2020, during the COVID-19 pandemic, production fell by 23 % [55].

In 2021 (according to the results of the State Statistics Service as of January 1, 2022, **Table 4.5**), the smallest decrease in the number of livestock and an increase in beef production is noted. Unfortunately, its consumption by the population decreased (**Table 4.3**), the produced meat in the form of deboned and frozen beef and veal in blocks was exported [56].

Analysts of agro-industry [49] explain the increase in export supplies of beef with the constantly growing need for animal protein of the global population. This, to a large extent, stimulates the cultivation of cattle for meat on a global scale. The main driver of cattle meat prices is Asian countries, especially China, as one of the main consumers of beef. According to the data of the Ukrainian Agribusiness Club [57], the Ukrainian meat market increased the volume of deliveries of Ukrainian beef abroad in 2021 to 27.55 thousand tons of meat, which is 11 % more than in 2020. According to thermal condition, 99 % of beef is frozen. Before the full-scale military invasion, the main beef exporters were the following countries: People's Republic of China – 12,330 tons, Republic of Belarus – 3,680 tons, Republic of Kazakhstan – 3,100 tons, Republic of Uzbekistan – 2,890 tons. At the same time, beef imports increased to 2.78 thousand tons, which is 34 % more than in 2020. Frozen meat was supplied to Ukraine the most – 1.94 thousand tons (70 % of total supplies), 0.84 thousand tons of chilled meat. The main suppliers of beef to Ukraine were Republic of Austria, Republic of Lithuania, Republic of Poland, and the United States of America. The given statistical data show that in the absence of state regulation on food safety issues, internal beef shortage, reduction of livestock, Ukraine increased exports.

The main suppliers of beef for enterprises with an average shift capacity of 10 tons of products per shift and above are large agricultural companies, which, as mentioned above, are concentrated in Central and Western Ukraine. Meat from industrial slaughter is brought chilled in half carcasses or quarters, or in the form of frozen blocks. Meat processing enterprises with a capacity of 1 to 5–7 tons of products per shift provide their raw material needs at the expense of the private sector, which is regionally concentrated. Slaughter of such animals is carried out, as a rule, without observing technological requirements. This testimony is the result of my own observations of the slaughter process at the processing enterprises of Southern Ukraine. The same conclusions were published by the FAO and the WHO – a significant proportion of animals are processed in inappropriate conditions, the basic requirements of slaughtering technology, cold processing, and storage are not met [58].

Under such processing conditions, the obtained meat raw materials have low functional and technological properties and require the inclusion of additional ingredients in the recipes that will

ensure stable quality indicators. Such additives to the main raw materials reduce the nutritional and biological value of the product as a whole. That is, meat products will not meet the requirements of food safety indicators.

After the start of the war on the territory of Ukraine, the situation with the production of livestock products has changed significantly. In April 2022, according to Taras Vysotskyi, First Deputy Minister of Agrarian Policy and Food of Ukraine, livestock farming in Ukraine was destroyed by 15 % of the total volume [59]. However, Olena Dadus, Deputy Director of the Department of Agrarian Development, during the "UA FARMING AT WAR TIME. LIVESTOCK FARMING IN FOCUS" webinar [60] reported that these losses are not critical for the food security of the state. Further actions at the front, the de-occupation of captured territories, made it possible to stabilize the situation with the supply of products to all regions of Ukraine.

Farms in the Kharkiv, Chernihiv, Kherson, Dnipropetrovsk, Zaporizhzhia, and Mykolaiv regions suffered significant losses. Destroyed buildings, dead animals and birds [61]. Under such conditions, products of animal origin, in the near future, may become a delicacy, which will worsen the supply of the human body with complete animal protein.

According to the calculations of the Ministry of Agrarian Policy and Food of Ukraine, the population of agricultural animals in agricultural enterprises and households as of January 1, 2023: cattle – 2,432,700 heads (the data do not match the data of the State Statistics Service [52], which can be explained incomplete information from farms in the conditions of hostilities); sheep and goats – 965,200 heads; pigs – 5,028,400 heads. As of April 1, 2023, the available livestock, heads of agricultural animals have changed: cattle – 2,505,267; sheep and goats – 332,065; breeding pigs – 79,740; commercial pigs – 3,410,798 [62].

As of April 1, 2024, according to preliminary data from the Ministry of Agrarian Policy and Food of Ukraine, 2 million 330.5 thousand cattle are kept in the domestic and industrial sector of Ukraine, including 1 million 263.8 thousand cows. Compared to April 1, 2023, the cattle population decreased by 172,400 heads (–7 %), including cows – by 91,100 heads (–7 %). About 39 % of animals are kept at industrial enterprises, and 61 % – at households. A certain slowdown in the rate of cattle herd reduction is noticeable compared to last year's period. For comparison, as of April 1, 2023, Ukraine lost 264,400 head of cattle (–10.6 %) and 138,400 cows (–10.25 %) compared to the same period in 2022.

Regionally, about 53.5 % of animals from the total cattle population are kept in farms of all categories in the following regions: Khmelnytskyi region – 215.8 thousand heads; Vinnytsia region – 187.3 thousand heads; Poltava region – 181.7 thousand heads; Ternopil region – 144.6 thousand heads; Odesa region – 136.9 thousand heads; Chernihiv region – 127,000 heads; Cherkasy region – 126.2 thousand heads; Zakarpattia region – 125,700 heads [63].

The difference in numerical values is explained both by the increase in the herd and by the emergence of the possibility to register an animal in the Register.

The significant difference in the data of the Unified State Register of Animals based on identified animals and the calculations of the Ministry of Agrarian Policy and Food of Ukraine can be

explained by the fact that in active combat zones there is no possibility to quickly provide up-to-date information on changes in the number of animals. However, it should be noted that the main share of farm animals is concentrated in the regions that were least exposed to rocket attacks and were not occupied. A more optimistic situation in animal husbandry in the Western part of Ukraine, in some regions, there is an increase in the number of certain species of animals, sheep and goat breeding have begun to revive. For example, in Prykarpattia, at the beginning of July 2022, the number of cattle in agricultural enterprises of the region increased by 0.8 thousand heads (7.8 %) and amounted to 11.1 thousand heads, including cows by 0.3 thousand heads (6.7 %) and, accordingly, 4,800 heads were kept despite the start of the war [64].

Our agrarians cannot provide an unequivocal forecast regarding the increase or decrease in the number of animals and poultry, the decrease in the cost of meat and meat products, milk and dairy products. Analysts of the Association of Milk Producers of Ukraine foresee an adjustment of livestock in farms due to the increase in the cost of the new grain crop by 70–80 %, compared to 2021 [65]. At the same time, problems with the sale of cereals can contribute to the use of a strategy where cereals are used for the production of compound feed and the cultivation of farm animals and poultry [66]. This strategy was confirmed by the increase in live weight livestock exports in January 2023 by 3.23 million USD, i.e., by 78.8 % compared to January 2022 [67].

At the same time, in the same January 2023, agricultural enterprises sold 8.1 thousand tons of cattle for slaughter, which is 11.11 % less than in January 2022. The main supplier of beef was small farms that produced 16.7 thousand tons of meat, however, they also reduced the total production by 5.39 % compared to last year. This situation is due to the increase in the cost of breeding and primary processing of animals, the absence or unstable supply of electricity and low demand for a product that is expensive for the average Ukrainian. These factors contributed to a decrease in beef exports by 1.11 thousand tons, which is 1 % less compared to January last year [68].

The greatest decline is noted in regions with active hostilities and significant population outflow. In regions where the situation is stable and the share of internally displaced persons has increased, the volume of beef production has increased. Difficulties in the domestic market are associated with a decrease in demand and an increase in prices.

The situation is similar with all types of animal husbandry products. According to the testimony of the "Ukrainian Club of Agrarian Business", in comparison with last year, in 2022 the production of all types of meat decreased by 11 % – equal to 3 million tons, milk by 12 % – 7.7 million tons, eggs by 18 % – 11.6 billion pcs [69].

According to the calculations of the National Academy of Agrarian Sciences of Ukraine for 2022 [70], in order to ensure the food security of the state, domestic processing enterprises must ensure the production of at least 8,230,000 tons of milk, 135,000 tons of beef, and 600,000 tons of pork, chickens – 1,620,000 tons, eggs – 14,100 million pcs [71]. In the conditions of active hostilities in a significant part of the territory of the state, unequivocally, no one today will be able to provide real statistical data regarding the conformity of previous calculations

and volumes of produced products, in particular, livestock products. It is difficult to determine the level of food security.

However, the reduction in livestock production does not pose a threat to food security in the country. The problem for the population is not in the quantity of produced products, but in their availability. A significant increase in prices for these types of products reduces their share in the general diet and limits the nutritional status of the population as a whole.

CONCLUSIONS

Based on the analysis of statistical data, it should be noted that in Ukraine over the past 33 years, the total cattle population has decreased to 2,307.1 thousand heads, as of January 1, 2024, which is 9.16 % of the 1990 population. This situation had a negative impact on citizens' consumption of food products made from animal raw materials, in particular, beef and its products. In 1990, the consumption of meat and meat products was 82.4 kg per person, which corresponded to 103 % of the recommended supply rate. Of the total share of meat and meat products consumption in 1990, beef dominated the diet – 46.48 kg per person per year. Over the next ten years, meat consumption decreased to 32.9 kg per person, which was only 41.1 % of the recommended norm, the weight of beef in the general diet was 15.5 kg per person per year. From 2000 to 2021, the share of ensuring the consumption of meat and meat products varied from 63.75 % to 69.25 %, the share of beef in the total mass of meat consumed decreased to 10.2 %. The decrease in beef consumption had a negative effect on the quality of nutrition. This is confirmed by the overall value of the Global Food Security Index, which determines food security in the country. In 2022, the level of food security was 70.2, the quality of consumed protein – 81.3.

It was established that the main reasons affecting the decrease in the share of beef consumption by Ukrainians are an unstable economic situation, a decrease in the income of the population of Ukraine, an increase in the price of beef and its products, and a decrease in the number of livestock in general. If to look at the war years 2022–2024, it is not possible to hope for an improvement in the situation with the consumption of beef by Ukrainians, for an increase in the quality of the consumed protein.

Therefore, without the development of cattle breeding, as a basis for adequate nutrition, the state will not be able to provide one hundred percent food security to our population.

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