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Analysis of the market of meat products in Ukraine

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Abstract. Meat and meat products are among the main products of the human diet, which contain the essential nutrients, biological, macro and microelements that are important for the full functioning of the human body. Due to the significant environmental impact associated with industrial meat production, combined with the ever-growing world population, it is important to investigate the current state and production of the meat industry. The purpose of the study was to determine the volumes and possibilities of production of certain types of meat products in Ukraine, their market share, prospects for production in the future, and the ability to provide food industry enterprises with raw materials for the production of new food products. The work was carried out by analysing scientific, regulatory and technical literature, statistical evaluation of data, and comparing the results obtained with the findings of other scientists. The analysis of the industry indicates the decline of certain areas in animal husbandry, in particular, cattle breeding and the production of meat, meat products from beef and veal; a decrease in the number of farm animals, namely by 23% of bovine cattle, 6.9% of pigs, and 2.4% of poultry. During the analysed period, poultry meat production increased by 17%, while the number of business entities increased by 25%. At the same time, beef and veal production decreased by 27.8%, while pork production increased by 33%. Based on the results obtained, it is possible to continuously provide processing enterprises with meat raw materials, namely, chicken meat for the production of meat products, and it is also relevant to introduce resource-saving technologies for obtaining a product with less weight loss and waste during processing. The study results can be used by enterprises when planning the release of products to the market, developing new recipes, improving existing production technologies, and understanding trends and volumes of meat and meat products on the Ukrainian market

Keywords: poultry processing; producer; food product; production technology; food security; animal husbandry

Introduction

According to the United Nations Population Fund (2023), the world's population was 8 billion in 2022. Due to the large number of people and the constant increase in population, there is a question of food supply, particularly meat and meat products. A complete diet directly depends on the consumption of animal protein. The production of meat and products from it also depends on the ability to produce and prepare animal feed, the number of farms, the allocation of land resources for raising livestock, etc. Given this and the possible food insecurity due to Russian aggression, the study of production volumes and trends in the development of the meat industry market in Ukraine is relevant.

A. Teixeira & S. Rodriguez (2021) found that the potential consumer is poorly informed about the benefits of meat products, in particular, health products that are presented on the market. The consumer does not always know how meat is produced and processed, does not pay attention to the physical and chemical composition or nutritional value, and only uses sensory assessment. As noted in the paper, the potential market for healthy meat products can only offer benefits for both healthcare and the meat industry if consumers consciously accept these products.

During the study of broiler meat production in the world, it was found that the specific share

of such meat from the total mass of chicken is 87-90%, and the production of chicken meat, in general, is developing faster than the world's population is increasing (Vissers *et al.*, 2019). The United States of America (USA) occupies a leading position in the world among the largest producers of chicken meat, while Europe, in order to improve its indicators, must optimise existing capacities and increase production by upgrading equipment and improving existing technologies, because it has used the existing reserve of land resources to build new production facilities (Sakhatskyi & Abdullaieva, 2014).

There is a relationship between livestock and food industries. Thus, the first one will experience some, and in some cases significant, impact due to the reduction of livestock, farms, and other enterprises for keeping animals. At the same time, processing enterprises and producers of finished products are increasing their capacity by obtaining raw materials through the slaughter of animals as a result of farm liquidations. Processors import a significant amount of raw materials, which negatively affects the economic efficiency of domestic producers. The lack of subsidies and other forms of state support also negatively affects producers in the meat industry. N.H. Kopytets & V.M. Voloshyn (2020) note that during changes and transformations in animal husbandry in Ukraine, processing enterprises should respond in time and anticipate the negative consequences with preventive measures. According to the researchers, poultry meat is the most profitable in Ukraine due to the constant investment in this industry and rapid payback of funds, an increase in production areas, and the demand of the country's population.

Researchers from India (Srutee *et al.*, 2022) examined the issues of farm animal meat production technologies and the challenges that await the world's population from consumption

in the future. According to the authors, due to the growing demand for meat among the world's population, it is possible that in the future it will not be possible to meet the demand for meat in kind. With this in mind, they were looking for alternative sources to replace the proteins found in meat. One proposal was to replace traditional animal meat with pure meat. This is an opportunity to obtain meat from animals without slaughter – by isolating the animal's cells and growing them in controlled growth conditions and environments that mimic the state *in vivo*. The meat and meat products produced using this technology are already on the market and have been sold for the last 5 years. Although consumer reviews are mixed about such a product and it is still necessary to consider a number of factors for the possibility of full-fledged production, namely, the nutritional properties, taste, shape, and structure of meat.

Considering the possibilities of meat production and food manufacturing, the population's demand for certain types of meat and the export opportunities of Ukraine, the question of rational processing of meat for maximum benefit and economic effect arises. In the food industry, various methods of preserving raw materials and food products, including meat, are used to extend the shelf life. One of such methods is drying. According to I. Pohozykh *et al.* (2012), it is best to dry high-grade veal with a fat content of 1.2%, turkey meat, and those types of meat that are characterised by a low content of adipose tissue. These products have higher nutritional and biological value and do not require large storage areas. Researchers also report that dried products have some functional and technological properties and can be used in the diets of geologists, athletes, and military personnel.

L.V. Molokanova and O.O. Oreshyna (2015) investigated the range of dried and cured

products made from various types of meat, which is presented on the Ukrainian market. According to the results, as of 2015, the share of products from chicken meat was 33%, pork meat – 22%, beef – 16%, horse meat – 11%, lamb – 8%, turkey – 6%, venison – 3%, and ostrich – 1%.

For the production of dried meat, raw materials should be low in fat, with high moisture binding capacity and an optimal ratio of muscle and connective tissues. Moreover, the production of dried meat allows avoiding some labour-intensive operations, reducing the duration of the technological process, and expanding the range of finished products (Pohozhykh *et al.*, 2013). This is also one of the most promising long-term storage products.

When developing new technologies for the production of meat products, it is necessary to consider changes in sensory characteristics and nutritional value indicators. As noted by I. Gómez *et al.* (2020), to obtain high indicators of the finished product, it is necessary to use combined processing and preservation technologies. At the same time, the production of minimally processed products is relevant for consumers. Some of the most popular and useful methods of canning and production are dry ageing (maturation of meat under controlled conditions), drying (reducing the moisture content of meat to extend the shelf life), fermentation (products with average moisture content and long shelf life) (Gómez *et al.*, 2020).

The purpose of this study was to analyse and systematise the Ukrainian market for the production of meat and meat products from various raw materials to determine promising areas for processing meat raw materials for the development of new products.

Materials and Methods

The materials of the study were scientific, technical, and official statistical information, which

was analysed and synthesised using the methods of theoretical and statistical research. The study was conducted within the framework of the dissertation research “Improvement of the technology for the production of meat delicacies using bee products” on the basis of the Faculty of food technologies and quality management of the agricultural products of the National University of Life and Environmental Sciences of Ukraine during October 2022-January 2023.

General methods and techniques were used, namely, abstract and logical methods: induction and deduction, analysis, synthesis, analogy, and comparison. Scientific and technical literature from the Scopus, Web of Science and Google Scholar databases was reviewed; regulatory and technical information from relevant institutions, organisations, and departments, in particular, the Ministry of Agrarian Policy and Food of Ukraine, the Ministry of Economy of Ukraine, the National Academy of Agrarian Sciences (NAAS) of Ukraine, the Institute of Food Resources of the NAAS of Ukraine, the State statistics service of Ukraine, etc. Abstract and logical methods were used to process theoretical information and analyse the actual situation regarding the general state of the meat and meat products market in Ukraine, and form tasks and conclusions of the study.

Keywords for the search of necessary information and data were: industrial production, food production, chicken meat, beef, pork, meat market in Ukraine, meat production in the world, export and import of meat, food industry enterprises of Ukraine, production volume, breeding of farm animals.

The data was received upon request from the State Statistics Service of Ukraine (2023). Statistical evaluation and comparison of the obtained data were processed using the built-in MS Excel statistical function package and are presented in Figures 1-7.

Data collection and analysis were applied to the production and processing of meat industry products, namely: the production of meat and meat products, including poultry meat and products made from it. Methods of analysis, synthesis, and comparison were used to investigate wholesale and retail trade in meat and meat products in Ukraine, including in specialised stores for the period 2014-2021. Data assessment and analysis were applied to information on the number of employees involved in the production of food products (including beverages and tobacco products) on a monthly basis over the past five years. The comparison was used to examine the level of production of chicken, pork, beef, and

veal in 2017, 2019-2021 in Ukraine. Methods of analogy, comparison, analysis, and synthesis were used to determine the number of existing business entities for the production of food products: meat (including poultry) and meat products in 2014-2020 in Ukraine.

Results

Breeding of agricultural animals by species

The production of meat and meat products directly depends on the number of animals kept in farms, industrial enterprises, or households. Figure 1 shows the number of farm animals (thousand units) that were kept by Ukrainian enterprises, namely cattle, in particular cows and pigs, for the period 2018.

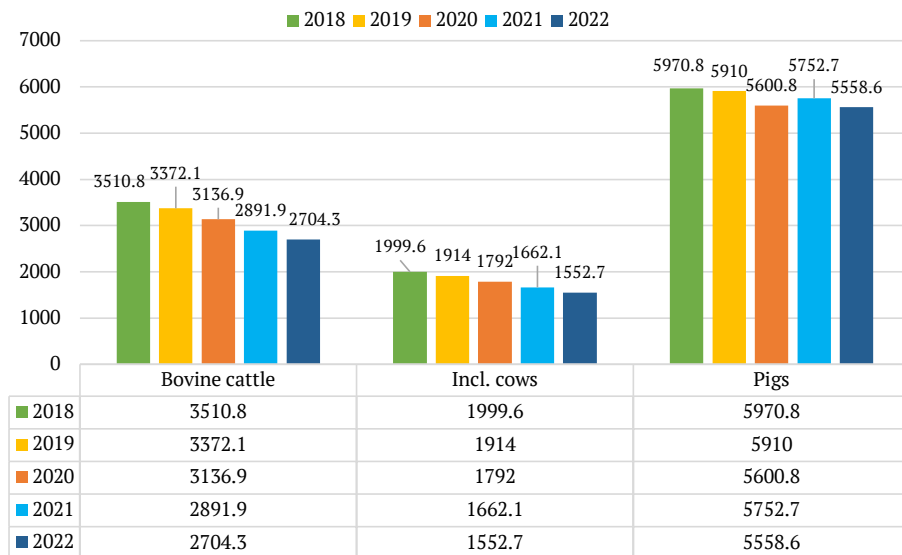


Figure 1. Number of farm animals, thousand units

Source: State statistics service of Ukraine (2023)

As can be seen from Figure 1, the situation with the number of cattle, including cows, over the past five years is complex and the number of animals is systematically decreasing. Since 2018, the number of cattle has decreased by 23%, and the number of cows has decreased by

22%. The reason for this phenomenon is the unprofitable breeding and keeping of animals, high-cost feed, and the high cost of veterinary drugs in this area. As a result, the price of meat which does not find much demand among buyers also increases. Regarding the situation with

the number of pigs, from 2018 to 2022, the number of pigs at Ukrainian enterprises decreased by 6.9%. Although there was a slight improvement in 2021, the number of pigs increased by 2.7% compared to 2020. Pork production in Ukraine is in second place among the production of various types of meat, although there is also a downward trend in the number of livestock. According to data and observations, this is conditioned by the unwillingness of

producers to engage in the cultivation and breeding of animals, periodic disease strains that require the destruction of all pigs, and high prices for maintenance and feeding.

Figure 2 shows the number of animal units of domestic poultry for the analysed period – 2018-2022. The number of poultry at the end of each study year is determined and presented as the largest and smallest number of birds during the year.

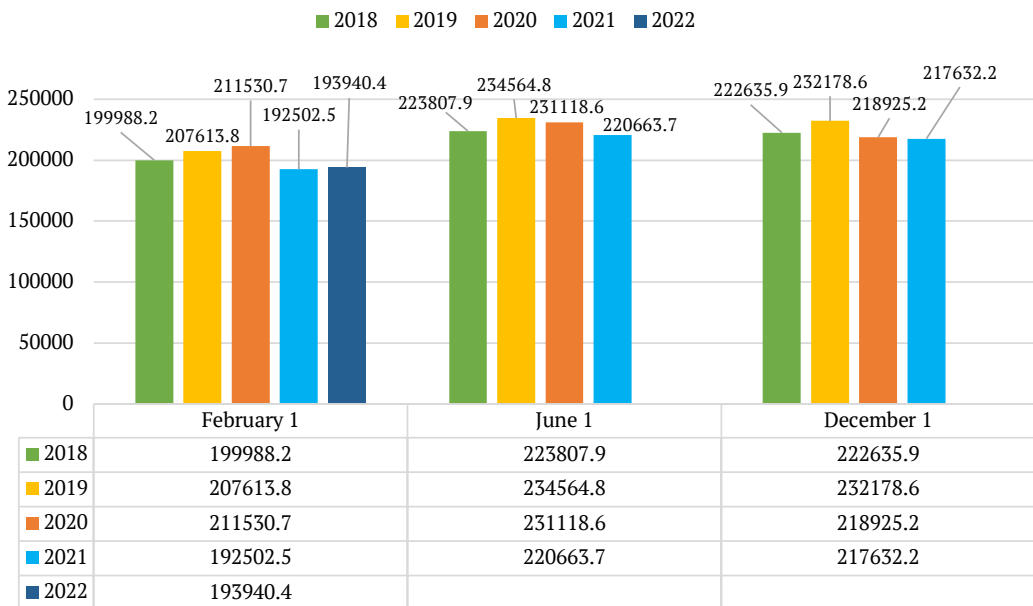


Figure 2. Number of poultry, thousand units

Source: State statistics service of Ukraine (2023)

Based on the data obtained from Figure 2, the largest number of poultry was kept in June, and the smallest – in February. Analysing the number of animals units at the end of the year (December), from 2018 to 2021, a decrease in the number of poultry was recorded by 5,003.7 thousand units (or 2.24%). As of 1 June 2019, the number of cows was 10,756.9 thousand more (4.8%), and in 2020 – by 7,310.7 thousand more (3.3%) compared to 1 June 2018. The State

statistics service of Ukraine has not yet released data since March 2022, but it is expected to dramatically reduce the number of poultry due to the full-scale invasion and war unleashed by the Russian Federation against Ukraine and the destruction of some of the largest poultry farms in Ukraine, where 4.4 million animals died (In Donetsk region..., 2022; Rising prices and a loss of 12 billion..., 2022). Nevertheless, considering the indicators of previous years and prospects

for the development and recovery of the poultry industry, it can be considered as promising and necessary for the Ukrainian market.

Production and sales volumes of meat products

When analysing the meat industry, it was important to consider the number of operating

business entities in Ukraine (Fig. 3) by categories: meat production, meat products production, and poultry meat production. The analysis was carried out for the period 2014-2021. It is determined in which year there were more business entities for the production of meat and meat products and how much the indicators have changed as of 2021.

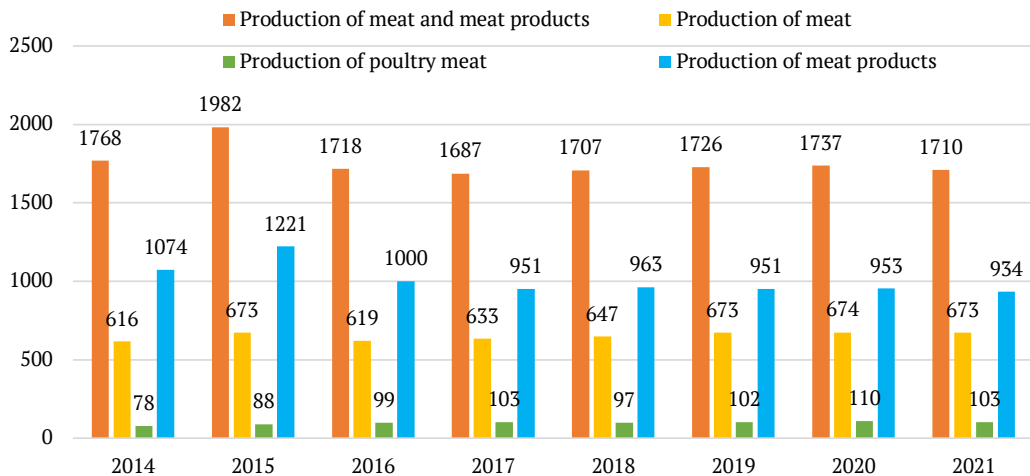


Figure 3. Number of operating business entities in 2010-2021

Source: State statistics service of Ukraine (2023)

Figure 3 shows that the largest number of business entities engaged in the production of meat and meat products was in 2015, and in the production of meat in 2020, with a difference of 1 entity compared to 2015, 2019, and 2021, in the production of meat products in 2015, and in the production of poultry meat in 2020. In general, during the analysed period, the difference by year was insignificant, so the number of business entities for the production of meat and meat products in comparison with 2014 decreased by 58 (3.3%) and by 140 (13%) for the production of meat products, but increased by 25 (32%) for the production of poultry meat and by 57 (9.3%) for production of meat. Given the dynamics of creating new business

entities, it is obvious that the production of meat and poultry meat is promising for profit.

The economy of each country depends on many factors, including the production of industrial products. The country's food security also depends on the production of basic necessities and food products in general. Ukraine has always occupied one of the leading places in the world in providing the population with agricultural and food products, so it plays an indirect role in global food security.

An analysis and comparison of the production of industrial products by type was carried out, namely, the production of chicken and chicken meat, pork, beef, and veal (Fig. 4).

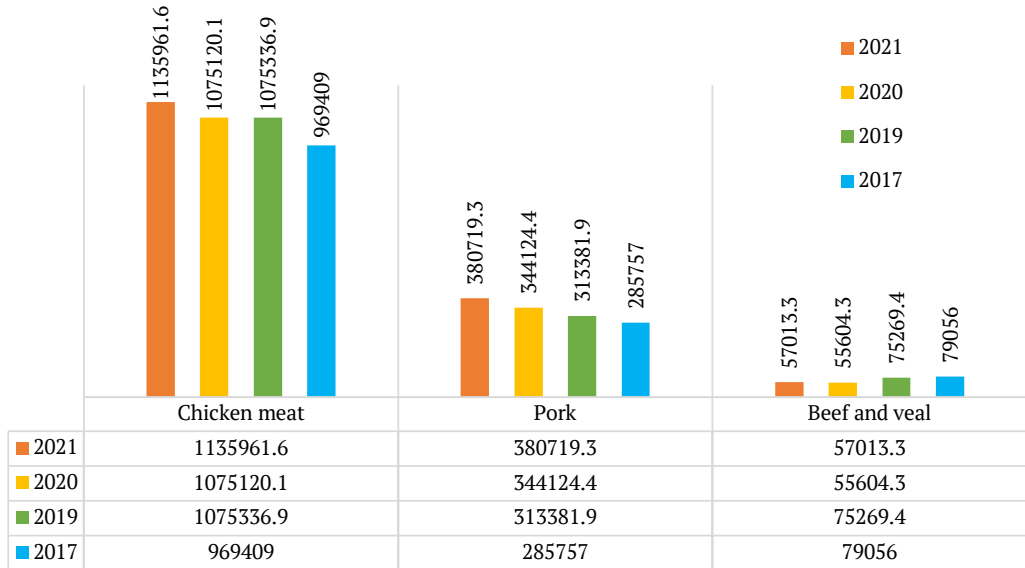


Figure 4. Production of industrial meat products by year, t

Source: State statistics service of Ukraine (2023)

A positive trend is observed in the production of chicken meat and pork, the opposite situation is observed in the production of beef and veal. Thus, during the study period (2017-2021), the production of chicken meat, namely fresh, chilled, and frozen, increased by 166,552.6 tonnes (or 17%); the production of pork (fresh, chilled, frozen, salted, in brine, dried or smoked) increased by 94,962.3 tonnes (33%); the production of beef and veal (fresh, chilled, frozen, salted, in brine, dried and smoked) has the negative indicator and their production decreased by 22,042.7 tonnes (27.8%). The correlation between beef and veal production indicators is associated with a decrease in the maintenance of cattle in farms of various capacities and forms of ownership in the livestock industry. High figures in terms of the number of poultry and chicken products produced once again confirm the prospects for choosing such raw materials when developing new products and improving existing poultry processing technologies for food needs.

The profitability of any production is always measured in monetary terms. An increase in the volume of products produced does not always lead to additional profit. Therefore, the volume of products produced by business entities in 2014-2020 per thousand UAH was studied. The same groups were chosen for comparison as in the previous times: production of meat and meat products, production of meat, production of poultry, and food production in general. The results obtained are shown in Figure 5.

Considering the data obtained, the volume of food production has been constantly growing since 2014. Thus, as of the end of 2020, compared to 2014, the volume of food products produced increased by UAH 311,538,053.4 thousand (or by 122%). However, in terms of the US dollar, the increase reaches only 23%, which indicates a high level of inflation. Regarding the production of meat and meat products, a significant increase in the volume of products produced occurred in 2017 (compared to 2016) – almost 2 times (98%). As of the end of 2020, compared

to 2014, the volume of meat and meat products produced increased by UAH 60,525,406 thousand (or 183%). Again, in terms of the US dollar, the increase reaches only 57%. A positive trend is noted in the increase in the volume of production of poultry meat in thousands of UAH. During the study period, the volume of poultry meat products produced increased by UAH 29,527,733.6 thousand (or by 253.5%). In terms of the US dollar, the increase over seven years reaches 96%, that is, 2 times. For comparison, the volume of meat production during this pe-

riod increased by UAH 16,398,630 thousand (or 286.7%), which is 115% in terms of the US dollar. But the category of meat production includes beef, veal, pork, horse meat, lamb, and goat meat, and the category of poultry meat includes chicken, turkey, and geese. Based on the results, the production and processing of poultry products, including chicken, will generate a more stable and constant income. Ultimately, the cost of production and processing of this product is lower compared to other types of meat and it will have a lower cost for consumers.

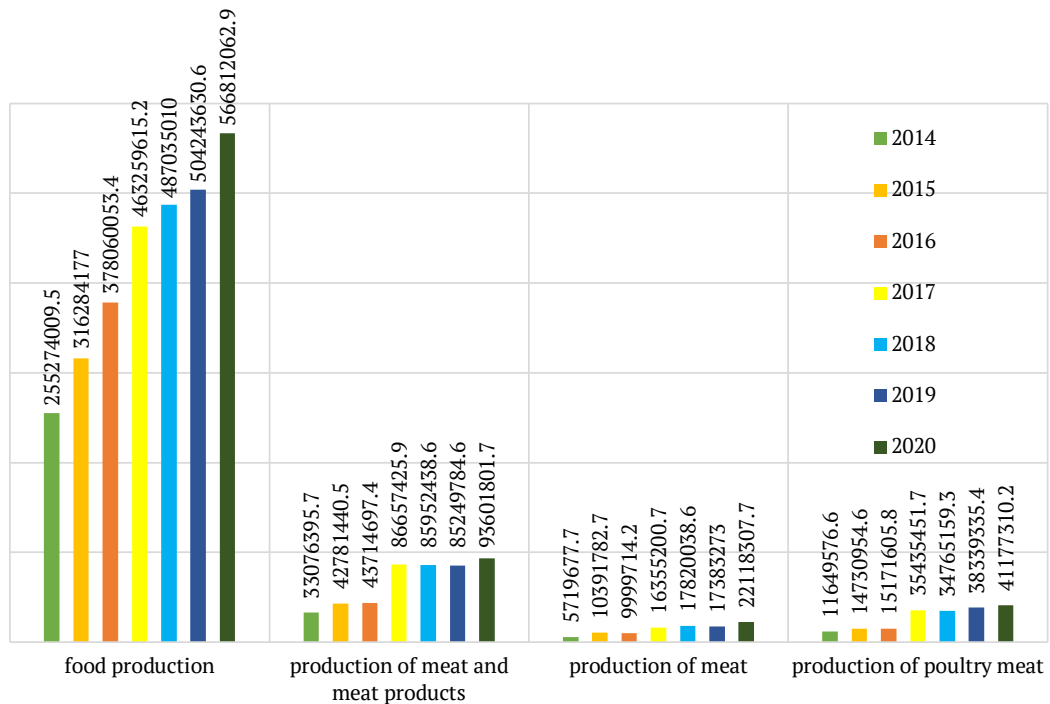


Figure 5. Volume of products produced by business entities in 2014-2020, thous. UAH

Source: State statistics service of Ukraine (2023)

Information on trade in meat and meat products produced in Ukraine was analysed and systematised. The data obtained are shown in Figure 6.

The manufactured products, namely meat and meat products, were sold through whole-

sale and retail trade in specialised enterprises. The manufactured products were sold both on the domestic market of Ukraine and were exported to different countries of the world. Retail trade in meat and meat products occupies only 7-9% of wholesale trade and is sold mainly

in branded stores of manufacturers. In accordance with the growth in production volumes,

trade is also growing, which is equivalent to thousands of UAH.

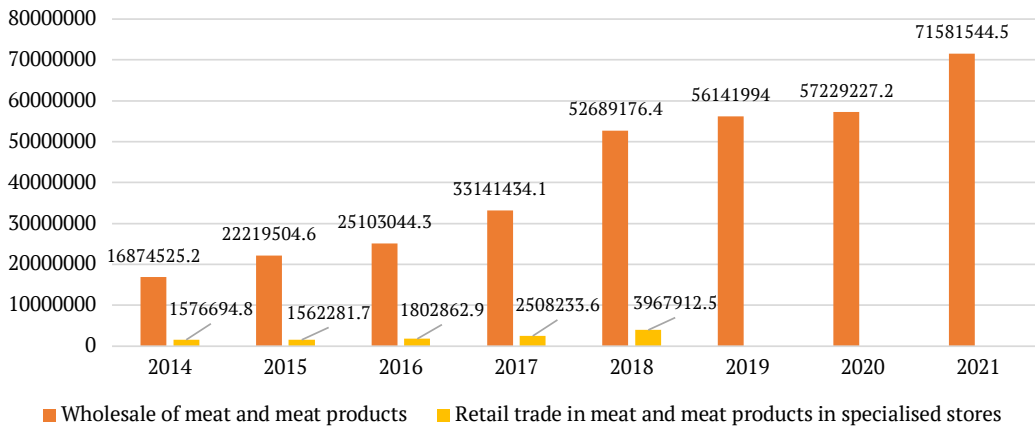


Figure 6. Trade in meat and meat products, thous. UAH

Source: State statistics service of Ukraine (2023)

Volumes of labour resources of food industry enterprises

The production of any product directly depends on the employees involved in it, so it was important to determine the number of

employees involved in the food industry. The average number of full-time employees involved in the production of food products (including beverages and tobacco products) by month is shown in Figure 7.

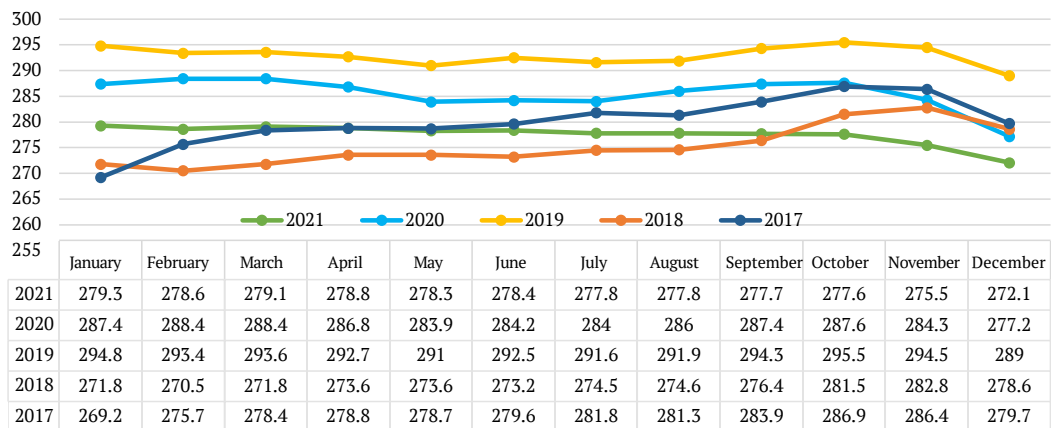


Figure 7. Average number of full-time employees involved in the production of food, beverages, and tobacco products, thous. people

Source: State statistics service of Ukraine (2023)

As can be seen from Figure 7, during each study year, there was a significant turnover of full-time employees who were involved in the production of food, beverages, and tobacco products. On average, at the beginning and end of the year, the difference between full-time employees is approximately 2-4%. The highest number of employees was recorded in March, July, and October. This is due to the performance of seasonal work, individual and specialised orders. The average number of employees by year was as follows: 2021 – 277,583 thousand people, 2020 – 285,466 thousand people, 2019 – 292.9 thousand people, 2018 – 275,242 thousand people, 2017 – 280,033 thousand people. Based on these data, there is a general trend towards a constant reduction in the number of employees (not including the figures for 2019). A number of factors contributed to the instability in providing people with jobs, including the COVID-19 pandemic and quarantine restrictions, low wages, the transition to automated production, hard physical and mental work (slaughterhouses), etc. As for the information for 2022, the State statistics service of Ukraine has not yet provided it, but a significant reduction in employees is expected due to the full-scale war of the Russian Federation against Ukraine, the closure and destruction of industry enterprises, the relocation of enterprises, including abroad, the transition to partial or fully automated production. Considering the data obtained, enterprises can anticipate various risk factors that they may encounter during their own activities: rely mainly on human labour to provide the necessary conditions for employees to minimise the flow of personnel, or develop the company's activities with a minimum number of employees, where the main work can be performed using equipment and not be dependent on providing employees.

Discussion

Analysing the research on the general situation of the state and production of the meat industry in Ukraine, it was also appropriate to consider the work of researchers who also studied such issues. Meat production is increasing, so over 50 years, the world's stocks of chickens and pigs have increased by 5 and 2.5 times, respectively. In Asia, meat consumption increased 15-fold during this period, while the population increased 2.6-fold. It is proposed to use more stable vegetable proteins in human diets in conditions where animal protein is not necessary and is of little use. This will reduce meat consumption in the future and at the same time greenhouse gas emissions, air pollution, water use, water pollution, and the incidence of major non-communicable diseases in developed countries (Poore & Nemecek, 2018; Espinosa *et al.*, 2020).

Considering the fact that meat production in Ukraine cannot fully provide the population with products, including due to its high cost, it is advisable to use animal protein substitutes to provide the body with the necessary nutrients – soybeans, beans, nuts, and dairy products. S. Grygoryev (2016) investigated the cost of poultry production in Europe, Africa, Asia, and America in comparison with Ukraine, and the impact of this indicator on competitiveness. The most expensive item in the production of poultry meat is feed costs, which in some places amount to up to 70%. Considering the cost price, the most expensive poultry meat production among the EU countries is Denmark and Italy, and the cheapest in Poland and Hungary. Among other countries, Argentina and Brazil have a lower cost of poultry production compared to Poland. Ukraine is one of the countries with the lowest cost of poultry meat production in the world.

Exports of meat and meat products from Ukraine increased after the country joined the

World Trade Organisation. However, A. Berher (2020) notes that unresolved problems in the development of meat and meat products producers are non-compliance of products with international quality and safety standards, insufficient state support for the sector, and low level of exports of some meat raw materials, in particular beef and pork.

A significant share in the consumption and export of meat in Ukraine is occupied by chicken, as well as cheap types of meat and meat products are in great demand. The largest producer of chicken meat and chicken products in Ukraine, in addition to raising chickens and producing meat, also produces frozen semi-finished meat products and frozen culinary products, which it supplies to the international market and increases exports every year (Kovinko *et al.*, 2016).

A.V. Harbar & R.L. Susol (2021) investigated the possibility of increasing the production of beef and, accordingly, beef meat products in the conditions of the south of Ukraine. They developed a technology for feeding young animals, where, subject to all the requirements and recommendations, it was possible to get a live weight of 500 kg of super-replacement stock within a year. According to the authors, Ukrainians do not have a clearly defined culture of beef consumption, especially in its natural form, and in most cases only in a deeply processed form. Moreover, due to the high cost of beef and veal, the population of Ukraine prefers poultry and pork. In addition, beef cattle breeding is only at the initial stage of its development, because the share of cattle of meat breeds in livestock enterprises is only 5% of the total number of livestock (Kozak & Hryshchenko, 2019).

Meat and meat products are essential for maintaining a healthy lifestyle and contain essential elements. In comparison with many countries of the world, where the production of cattle meat is a profitable and promising

business area, in Ukraine such production is unprofitable. Insufficient investment and subsidies from the state in the sector of keeping cattle by enterprises and producing beef and veal meat lead to catastrophic consequences that may even threaten the country's food security (Koshel, 2019). Measures to stimulate domestic pork consumption in Ukraine were investigated by S.Yu. Sokolyuk *et al.* (2022). According to the researchers, Ukrainians consume 30-40% less meat than residents of the European Commonwealth countries. The main problems that hinder the progressive functioning of the meat processing complex are the disparity in production prices and the ability of the population to buy products, the decline in production, inflationary processes, etc. For sustainable and efficient pork production in Ukraine, it is necessary to introduce economic management at enterprises. V.M. Lesyk & N.O. Kovalenko (2018) note that the main management process should consist not only of production aspects, but also of the entire activity of the enterprise. Researchers also note that an intensive approach to the development of the enterprise will contribute to a gradual increase in production capacity and increase the productivity of animals, which will provide more meat. The current state of pork production in Ukraine has been studied by I. Chernyshov and M. Levchenko (2018). According to their research, under the influence of imperfect economic conditions of production, the pig industry is in decline. The authors argue that Ukraine is on the verge of a critical border of food security due to a multiple decline in pork production and low consumption by the population. L. Stepasiuk (2019), like most researchers, when studying pork production in Ukraine, notes the urgent need for state regulation and intervention in solving the problem of the unprofitability of the industry. In addition, there are problems in providing the population

with high-quality and safe products, ensuring food security of the state and the economic efficiency of pork production. Summarising the analysed statistical data and results of other researchers, the development of pig breeding has stopped and pork production has decreased.

O. Dovgal (2020) investigated the meat and food sub-complex of the agro-industrial complex. The researcher notes that due to the import of live animals, meat raw materials and products, offal, and other products of animal processing, the need for Ukrainian industrial enterprises to form and support the development of their own raw material zones is reduced. In addition, the expansion and monopolisation of the market by agriholdings, which are mostly focused on the foreign market, pose a threat to the stability of domestic supply of meat and meat products.

According to the S.A. Sehedá (2020), in Ukraine the decline of certain livestock industries is caused by different consumption of meat and meat products by the population and non-compliance with the rational consumption rate. The main factor in the consumption of meat and meat products is the level of wages of the population. Accordingly, with the increase in income, the consumption of products increases significantly, which has a positive impact on the overall development of production. The decline in the number of livestock and the production of meat and meat products has a negative impact not only on the agricultural sector but also on the provision of affordable meat products to the population. L. Fushtei (2020) notes that it is the meat market that is strategically important and significant for ensuring the food security of the state. In Ukraine, only poultry production is actively developing among the products of the meat and food sub-complex, which occupies a predominant share. A significant share of pork, beef, and veal

production is concentrated in households. The increased production of meat and meat products is conditioned by a significant reduction in the number of cattle and pigs (Fushtei, 2019).

For many years, scientists have been trying to create meat using the laboratory method (Sharma & Kaur, 2015; Mayhall, 2019; Van Loo *et al.*, 2020), which could replace natural products from farm animals. In 2013, the world's first laboratory hamburger made from muscle cells was created. However, the developed sample could not be scaled to an industrial scale due to its high cost of USD 300,000 and the imperfection of the meat itself. The researchers developed and discussed the design of micro-carriers for skeletal muscle cell proliferation and then for meat production (Bodiou *et al.*, 2020).

One of the factors that affected global meat production, supply chain, and prices was the COVID-19 pandemic. One of the reasons for the massive rise in the price of raw materials and meat products, the researchers cite panic purchases at the beginning of the pandemic and a decrease in meat production. M. Ijaz *et al.* (2021) noted that a large number of meat processing plants began to close due to worker illness, and also due to workforce reductions, restrictions on the movement of animals within countries, and changes in local and international export market regulations. Integration between all stakeholders in the meat industry is essential to ensure the sustainability of the supply chain and avoid similar challenges in the future. According to the authors of this study, Ukraine also recorded a rise in the price of meat and meat products during the beginning of the pandemic, as well as problems in ensuring the full functioning of industry enterprises.

Researchers from around the world, in particular, the United States, England, Sweden, and Norway, have studied infectious diseases that arise from the consumption of animal meat

and the role of animal husbandry and meat production in the spread of infectious diseases (Tschofen *et al.*, 2019; Willett *et al.*, 2019). They note that raising animals and producing meat in households most often leads to infection and transmission of diseases. The researchers also described various infectious diseases that negatively affect meat production, and, accordingly, the economy of countries and the environment. Infectious diseases are one of the reasons that lead to a reduction in the production and consumption of meat and meat products. The main changes that help to control the situation and respond to any risks in a timely manner are the adoption of a number of laws of Ukraine, namely Law of Ukraine No. 771/97. "On Basic Principles and Requirements for Food Safety and Quality" (2023), Law of Ukraine No. 2498-XII. "On veterinary medicine. Law of Ukraine 2498-XII" (2023). Given the results of researchers from Ukraine and around the world, which have been analysed and discussed in this paper, as well as the results of this study, the issue of meat and meat products production and the development of the meat industry, in general, is of utmost importance. The papers by the above-mentioned researchers coincide with the data obtained in this study on the reduction of certain types of farm animals, filling the market with cheaper products, obtaining large production volumes due to the introduction of resource-saving technologies and increasing animal productivity, and monopolising the market in certain areas of the meat industry.

Conclusions

In the course of the study, the current state of meat and meat products production in Ukraine, the volume of goods produced, and the number of full-time employees for food production were analysed and evaluated. It was determined how many business entities in various spheres

of economic activity were valid on the territory of Ukraine, data on the number of farm animals at Ukrainian enterprises and how the products are sold were presented. As for the number of agricultural animals kept by Ukrainian enterprises, their number has significantly decreased in recent years. The worst situation is observed with the rearing of cattle and, accordingly, the production of beef and veal. The results obtained also coincide with the findings of a number of researchers. Thus, over the past 5 years, the number of cattle, including cows, has decreased by 23%, pigs – by 6.9%, and poultry – by 2.4%, despite the best indicators and prospects among other agricultural animals. Investigating the production of industrial products by individual types, it was found that the production of chicken and chicken meat increased by 17%, pork production increased by 33%, and beef and veal production decreased by 27.8%. In some cases, production increased due to a sharp decrease in the number of animals and sending them for processing.

The volume of manufactured products, namely food, meat and meat products, and poultry meat, measured in thousands of UAH, increased from 98% to 122% over the 2014-2020 period, and in some cases even up to 253% and 286%. However, in terms of the US dollar, these indicators range from 23-57%, 96-115%. This indicates a high level of inflation during these years. Regarding the introduction of technologies for creating meat by laboratory method in Ukraine to provide the domestic market with meat products, the authors suggest that this is impractical. And given the results of the study and the socio-economic situation of the country as a whole, it is irrational and unrealistic. It is important to establish the production of certain types of products at existing facilities, introduce the latest technologies to ensure continuous production, control the quality and safety

of products in accordance with international standards, and help at the state level to stabilise the situation in the field of animal husbandry and production of meat and meat products.

In general, the production and trade of meat and meat products in Ukraine has great potential, due to the large reserves of land resources for growing animal feed, keeping farm animals on farms, industrial enterprises or households, and the possibility of building new facilities for the production and processing of livestock products and the manufacture of new food products. It is important to prevent the ever-increasing unprofitability and the possibility of the disappearance at the industrial levels of certain areas of animal husbandry, in particular, bovine cattle and pigs; transformation of poultry production into monopolistic market ownership. Consideration of the recommendations of scientists and an effective and rational approach on the part of the state to ensuring

the proper functioning of the agro-industrial complex will have a decisive place in ensuring food security in Ukraine.

It is appropriate to conduct future studies on the properties of chicken meat, as the most common on the Ukrainian market and promising in terms of production in the future. It will also be relevant to investigate changes in the structure and properties of chicken meat due to the influence of various methods of processing raw materials. Studies on the possibility of improving production technologies through the use of combined technologies to extend the shelf life of products and their use in specialised food will be promising.

Acknowledgements

None.

Conflict of Interest

None.

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Анотація. М'ясо та м'ясні продукти є одними із основних продуктів раціону людини, що в своєму складі містять необхідні біологічні та поживні речовини, макро та мікроелементи, які важливі для повноцінного функціонування організму людини. Через значний вплив на навколишнє середовище, пов'язане з промисловим виробництвом м'яса у поєднанні з постійно зростаючим населенням світу, актуальним є дослідження діючого стану та виробництва м'ясної промисловості. Метою роботи було визначити обсяги та можливості виробництва окремих видів м'яса та м'ясної продукції в Україні, їхню частку на ринку, перспективи щодо виробництва в майбутньому, можливість забезпечувати підприємства харчової промисловості сировиною для виробництва нових харчових продуктів. Виконання роботи здійснювали за допомогою аналізу наукової та нормативно-технічної літератури, проведення статистичного оцінювання даних та порівняння отриманих результатів з дослідженнями інших науковців. Аналіз промисловості вказує на занепад окремих напрямів у тваринництві, зокрема вирощування ВРХ та виробництва м'яса, м'ясних продуктів з яловичини та телятини; зменшення кількості сільськогосподарських тварин, а саме на 23 %

ВРХ, 6,9 % свиней та 2,4 % свійської птиці. За аналізований період виробництво м'яса птиці зросло на 17 %, а кількість суб'єктів господарювання збільшилося на 25 %. Водночас на 27,8 % зменшилося виробництво яловичини та телятини, а виробництво свинини збільшилося на 33 %. Враховуючи отримані результати є можливість безперебійно забезпечувати переробні підприємства м'ясною сировиною, а саме курячим м'ясом для виробництва м'ясних виробів, також є актуальним впровадження ресурсозберігаючих технологій для отримання продукту з меншою втратою маси та відходами під час перероблення. Результати дослідження можна використовувати підприємствам під час планування випуску продукції на ринок, розроблення нових рецептур, удосконалення існуючих технологій виробництва, розуміння тенденцій та обсягів м'яса, та м'ясних продуктів на ринку України

Ключові слова: переробка птиці; виробник; харчовий продукт; технологія виробництва; продовольча безпека; тваринництво



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Physiological and biochemical aspects of the carp organism in conditions of increasing their viability when stocking water bodies

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Abstract. The relevance of the study is conditioned by the defining role of the stage of early development in the ontogenesis of young fish in the formation of their growth rate potential. The physiological and biochemical status of the body determines the adaptive capabilities of hydrobionts, so the use of biologically active substances when rearing fish was chosen as one of the vectors for improving the development parameters. The purpose of the study was to determine the effectiveness of introducing technological elements (supplementary feeding, rearing) in the early stages of the ontogenesis of young fish. The study was based on theoretical (analysis, synthesis, comparison, modelling), experimental, and laboratory methods adopted in fisheries, physicochemical studies. A clinical examination of fish, monitoring of growth rates, weight gain, survival rate, and physiological state was carried out. The results show an increase in the viability

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of young fish, activation of metabolic processes, and improvement of blood morphological and functional parameters. The average weight of fingerlings exceeded the parameters in the control group for carp by 3.5% and for silver carp by 3.8%. The total number of red blood cells in the silver carp experimental group was 7.4% higher than the control ($p < 0.05$), haemoglobin content – by 4.7%, haematocrit – 9.9%. The total number of red blood cells in the blood of carp in the experimental group was 4.9% higher, and the haemoglobin content was 3.1% higher than in the control group. In the experimental group, the total protein content exceeded the value in relation to the control group for silver carp by 15.9% ($p < 0.05$), and for carp – by 23.9% ($p < 0.01$). Enzymatic activity in the experimental group was higher compared to the control group. The proposed method of feeding helps increase the growth rate of fish. The practical value of the study is to help improve qualitative and quantitative parameters, in particular, the biochemical composition of the muscle part for carp and silver carp in samples in the experimental group in comparison with control values

Keywords: functional status; hydrobionts; technological elements; resistance; rearing

Introduction

Rational fisheries management, both the actual aquatic bioresources and the potential of fisheries enterprises, is one of the key aspects in the context of effective compensation programmes for stocking and replenishment of the ichthyofauna with resilient fish planting material. Improvement of the strategy for the development of fisheries, harmonisation of fish production in natural and artificial reservoirs with the maximum use of the potential of water resources, and consideration of physiological, ichthyological, and breeding aspects are dominant vectors in this area. Therefore, complex research on optimising technological elements and rational use of industry resources come to the fore (Buzevych, 2012; Bekh *et al.*, 2014; Heina *et al.*, 2015). Rearing fish planting material, increasing the level of resistance of the body of hydrobionts to the influence of various factors, and improving the development parameters of young fish are a prerequisite for the promising and sustainable development of the fisheries industry as a whole (Şen *et al.*, 2017; Honcharova *et al.*, 2019; Tsurkan *et al.*, 2019).

In the context of modern realities, many studies focus on the need and expediency of reloading individual elements and technological systems of the fisheries industry. Moreover, it should be borne in mind that the transformation of a number of parameters of different nature: physicochemical, hydrobiological, physiological and biochemical, ecological and biological in aquatic ecosystems occurs in accordance with the adaptive capabilities of the aquatic organism (Honcharova *et al.*, 2021). Aquatic ecosystems form a certain number of parameters in accordance with climatic transformations in modern conditions. At the same time, the mechanisms of neuro-humoral regulation in the body of hydrobionts are aimed at maintaining the parameters of homeostatic balance. A single functional system in the body of introduced hydrobionts or native ichthyofauna should be aimed at regulating and ensuring the constancy of vital parameters, increasing adaptive capabilities, and in some cases, the ability to globally rebuild a link of adaptive and compensatory mechanisms in order to stabilise

vital functions. Under stressful situations that may be caused by the discrepancy between neuro-humoral regulation on the influence of abiotic and biotic factors, the functional status of the fish body will have a decrease in resistance to negative effects, low development parameters, and deterioration of the reproductive ability of hydrobionts. Under such conditions, it is important to implement comprehensive system solutions with a vector of corrective and modelling effects on the fish body. In this context, the course of metabolic processes in their body forms qualitative and quantitative parameters: the rate of development in ontogenesis, survival, productivity, etc. These aspects are among the priorities in the development of strategic programmes for optimising the production of viable young fish for effective stocking of reservoirs of various shapes and purposes.

Some researchers emphasise the need for rational use of water resources, harmonisation of trophic relations, and qualitative and quantitative parameters of fish against the background of environmental conditions of a certain water area (Sherman *et al.*, 2017; Korzhov & Honcharova, 2020). Climatic transformations, technogenic load on ecosystems, rapid development of technologies and their introduction into the technological scheme often contribute to the “discrepancy” of physiological and biochemical mechanisms, and adaptive capabilities of the body of hydrobionts. As a result, there is a chain of consecutive changes: stress reactions in the body of hydrobionts, a decrease in the indicators of effective management of the industry, irrational exploitation of resources, etc.

Under these conditions, one of the solution cases is the need to reconstruct the ichthyofauna of water areas and develop certain comprehensive recommendations. In the conditions of rearing and introducing resilient fish planting material of commercial fish species, there are

opportunities for successful implementation of the programme to achieve positive results and solve a considerable number of issues of fisheries activities. Researchers provide informative and objective data on a significant reduction in fish planting material for carp stocking in water areas, the need to review the main aspects of strategic programmes for the development of the fisheries industry. Given these aspects, there is an urgent need to update the ichthyofauna, thereby determining the topic and relevance of research in this line (Buzevych & Heina; 2019; Averchev *et al.*, 2019; Shcherbak *et al.*, 2020).

Summarising these aspects, it is worth noting the relevance of scientific and practical work in optimising certain elements at the stage of rearing young hydrobionts. Given that there is a rapid development of technologies, transformations in the context of abiotic and biotic factors, and the body of hydrobionts must adapt to the leading factors, studies on the possibilities of improving the adaptive capabilities of the body, activating metabolic processes, improving the speed of development of hydrobionts acquire practical and scientific value. To achieve these objectives, the aim was to study the influence of the technological factor on the main physiological and biochemical parameters in the carp organism at the rearing stage through a comprehensive study.

Literature Review

The researchers substantiate the importance of increasing the production of fish planting material in modern ecological and technological conditions for the purpose of further stocking of water areas, restoration of ichthyofauna, and rational fisheries management of reservoirs for various purposes (Shcherbak *et al.*, 2020; Regional report on the state of the environment of the Kherson region 2001–2021, n.d.). Adaptive

and compensatory mechanisms of hydrobionts are rearranged in their body depending on the abiotic and biotic factors of the environment where they are located. Introduced hydrobionts should occupy the corresponding trophic niches of the aquatic environment. Admittedly, it depends on the availability of the food resource of the aquatic ecosystem and their ecological and biological characteristics. Rational exploitation of water bodies, considering the biological needs of water bodies, will ensure efficient fishery use of water areas (Buzevych & Heina, 2019; Sherbak *et al.*, 2020).

Given the practical value of the outlined range of problems, the decisive role of optimising the technological and biological aspects of fish farming can be noted, in particular, carp in polyculture in the context of the growing cycle. The researchers focus on revising the main parameters and technological aspects in the conditions of modern climatic transformations, including fish wintering and the stages of rearing (Boychenko *et al.*, 2016; Tsurkan, 2022). There are authors who focus on the prospect of using enzymatic compounds, prebiotics, and drugs aimed at correcting the feed conversion rate and improving the overall fish-biological indicators (Hoseinifar *et al.*, 2017; Ziótkowska *et al.*, 2020). However, it is important to consider the bioavailability of each of the ingredients for the body of hydrobionts, the specificity of action and the features of physiological and biochemical processes. In this context, the issue of using “environmentally friendly” substances as part of additives or separately in aquaculture is relevant. This method brings technological aspects closer to “organic production”, which in modern conditions tends to increase demand among producers of aquaculture products and consumers. It is proposed to introduce various problem-solving cases at certain stages, when the potential for the development of hydrobionts is

formed. In particular, the introduction of components in the feeding of hydrobionts of active substances are of natural origin, as close as possible to environmentally friendly ones. Promising results on the introduction of biologically active, specially processed or non-traditional components of the general diet of hydrobionts in the general technological scheme are reflected by some researchers (Pivovarov *et al.*, 2017; Palamarchuk *et al.*, 2018; Pratiwy *et al.*, 2020).

The effectiveness of optimisation measures in the context of technological aspects is ensured by comprehensive in-depth studies of the environment for hydrobionts and conditions of resource feed potential (Korzhev, 2020). N.I. Kulbida (2004), O. Honcharova *et al.* (2021) focused attention on the expediency of developing strategic solutions for restarting the fisheries sector, considering the impact of climate parameter transformations both at the regional and global levels (FAO, n.d.; Intergovernmental Panel on Climate Change, n.d.).

Based on the above, there is a need to develop and implement innovative and ecological technology for the production of fish farming products and rational operation of reservoirs. Comprehensive optimisation measures of the technology of rearing fish planting material, depending on modern environmental and technological factors, will contribute to complementing the general idea and successful search for the optimal model for growing young fish. The relevance of obtaining high-quality viable fish planting material remains even in modern conditions of development of the fisheries industry.

Materials and Methods

The research is focused on the main experimental part of the component, which was performed at the premises of the Department of Water Bioresources and Aquaculture of KSAU (Ukraine), laboratories at the Faculty of

Fisheries and Nature Management of KSAU and state institution (SI) "Kherson production and experimental plant for breeding and rearing young common freshwater fish. The Department of Aquaculture of the National University of Life and Environmental Sciences of Ukraine (NUBIP) analysed and developed the feed mixture, which, after the preparatory stage, was transferred to the Department of Water Biore-sources and Aquaculture of KSAU for the main part of research: feeding and rearing carp in an experimental study. Copyrights for the use of technological elements of supplementary feeding, the composition of the feed mixture, and the use of a method to increase the viability of young fish are secured by the authors of developments of the Department of Water Bi-oresources and Aquaculture of Kherson State Agricultural University.

The fish diet was optimised in compliance with generally accepted recommendations (Zhel'tov, 2003; Hrytsyniak, 2007;). For the production needs of the operation of pool systems, a solar panel was used as an additional energy source with the installation of elements for the use of additional filtration in fish pools using agricultural crops and materials capable of filtering water coming from the reservoirs of the system at a certain level. The developed scheme for rearing fish planting material of young carp *Cyprinus carpio* is proposed in polyculture with a silver carp hybrid *Hypophthalmichthys hybrid* was used in the research group. The results were compared with the control group. Technological aspects of the experimental study are as follows: a system of recirculation pools, for the experiment, 250 m³ tanks with appropriate equipment, elements of filtration sections, a built-in autonomous section (unit) for the cultivation of microalgae with a timer for the correction of light and hydrochemical conditions. All parameters were monitored systematically

and recorded in the work log. In each tank, there were *Cyprinus carpio* larvae for rearing in poly-culture with *Hypophthalmichthys hybrid* with initial weight up to 400 mg (average 0.325 mg). When planting fish for rearing, samples of 260 specimens were selected into the formed groups to analyse the parameters of the physiological and biochemical state of their organism. Blood and other biological samples were taken from 50 specimens (Dehtiarov, 2001). At the end of the experimental study, the functional state of the body of carp and silver carp fingerlings was studied before and after stocking water areas.

At the beginning of the preparatory stage of experimental work, the model basin system was installed and tested in the conditions of laboratory research of KSAU and SI KPEP. Feeding at various stages of fish ontogenesis was carried out in accordance with the current standards in fish farming. At the same time, the size and dispersion of particles and granules were gradually changed to increase their bioavailability. At the time of the transition of fish larvae to mixed nutrition, these components were introduced gradually. They were cultivated in a bioreactor, followed by filtration and processing. The culture obtained from the mother liquor of its own cultivation in a medium based on water treatment was develop for introduction into the fish diet based on the calculation of 1:3 and 1:2 working solution of *S. Platensis*: humic substances of a commercial preparation of 15 mg per kg of feed, while the feed particles were evenly distributed and sprayed. The technological factor was thus a feed mixture and filtration conditions involving not only classical energy sources, but also alternative ones (solar panels).

The hydrochemical state of the tanks was monitored according to standard parameters based on the monitoring schedule. The aquatic environment is a single ecosystem for hydrobionts, which has a direct impact on

the formation of all processes and the level of functionality of their body. At this stage, monitoring studies were carried out systematically in accordance with the planned schedule, which allowed analysing the trend towards changes and fluctuations in each of them. Consequently, the temperature regime and the level of free hydrogen ions (PH) had an average value of 24.3-24.4°C (with a gradual decrease) and 7.3 units. With the development and stabilisation of the main homeostatic indicators of the body of young fish *Cyprinus carpio* and *Hypophthalmichthys hybrid*, the actual temperature value was reduced to gradually adapt to hydrochemical changes in parameters after stocking of already grown juveniles. The actual values of the hydrochemical state for the leading parameters were within the maximum permissible concentrations (MPC). At the time of the introduction of the feed mixture, the pH of the aquatic environment in the basins of the system fluctuated slightly, which is a reasonable phenomenon, the difference did not exceed 1.0 units. The oxygen regime had an average value of 3.8-4.0 mg O₂ against the background of nitrite concentration NO₂⁻ 0.02-0.03 and nitrates NO₃⁻ 0.14-0.15 mg N/dm³. In general, the hydrochemical regime during the rearing of hydrobionts in reservoirs created an ecosystem of the aquatic environment optimal for the life of young fish in terms of basic parameters.

In addition, in parallel with laboratory studies, systematic sampling and monitoring of hydrochemical parameters of the water area where it was planned to carry out stocking of reared young fish were carried out. During the growing season, the average temperature of the aquatic environment ranged from 20.8 reaching peak maximum individual actual values of 28.2°C. The content of oxygen dissolved in water ranged from 6.8 to 7.2 mg/dm³, at the same time, the level of hydrogen ions pH was in the

range of 7.6-7.9 units, ammonium nitrogen had values at the level of 0.3 to 0.4 mg/dm³. The content of nitrites did not exceed the maximum permissible concentration of 0.001, and nitrates – 0.4 mg N/dm³.

The studies of the main parameters were guided by generally accepted methods (Hrytsyniak, 2001; Dehtiarov, 2001; Zheltov, 2003; Arsan *et al.*, 2006). All the necessary equipment was available in the conditions of a certified laboratory of KSAU, SI KPEP, ThermoMix was used to transport biological samples. The functional status of the fish body was assessed by the leading parameters of biological material: biochemical analysis of samples to study the level of enzymatic activity of alanine aminotransferase (ALT), aspartate aminotransferase (AST), total protein content, and glucose concentration was carried out in the laboratory of the Department of Water Bioresources and Aquaculture of KSAU on the Humalyzer 3000 analyser using Human GmbH unified kits. Catalase activity was determined by spectrophotometric method, based on the ability of hydrogen peroxide to form a stable colour with the reagent. Morphological and functional parameters of blood (total number of red blood cells, white blood cells, haemoglobin content, corpuscular parameters of blood) were analysed using standard methods using test kits and counting method. Against the background of the outlined parameters, the ethology of hydrobionts was monitored during the day. All manipulations with experimental objects corresponded to the “European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes” (1986).

Results and Discussion

The functional status of the fish body reflected the course of metabolic processes and the level of resistance to various environmental factors.

Therefore, first of all, the hydrochemical regime in the system of cultivation of research objects should be noted. The results of monitoring the rate of fish development are presented as a di-

agram in Figure 1. The average weight of carp and silver carp corresponded to the general recommendation parameters and was higher than in the control group.

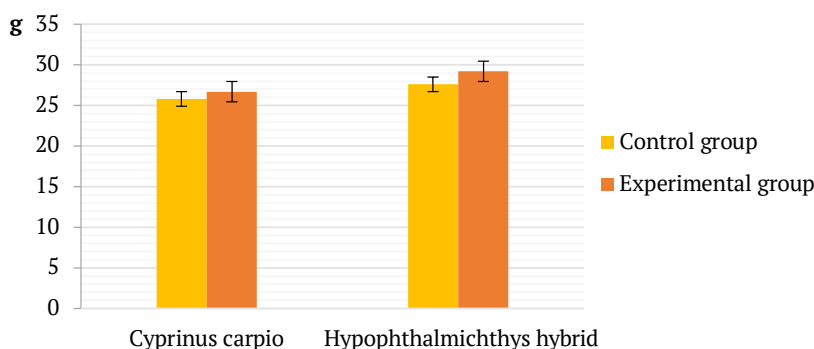


Figure 1. Comparative analysis of development parameters *Cyprinus carpio* and *Hypophthalmichthys hybrid* fingerlings, ($M \pm m$, $n = 260$)

Source: developed by the author based on own research

In addition, against the background of higher development parameters, the survival rate of hydrobionts in the experimental group after feeding was higher than in the control group, as evidenced by higher growth rates in the group where the feed factor played the role of a stimulator of metabolic processes. Admittedly, the aquatic environment creates optimal or opposite unfavourable conditions for the viability of hydrobionts, maintaining the parameters of their homeostatic equilibrium, however, the feed factor also indirectly corrects these parameters.

Physiological and biochemical parameters of the carp body in the experimental group, where the juveniles were grown using several technological factors (improved filtration,

optimisation of feeding conditions), were noted as the highest indicators in comparison with the parameters of the control group. Since the entire system functions in symbiosis, with a certain appropriate reflection on the influence of abiotic and abiotic factors, the carp blood test is an informative and important study. It informs about certain changes in neuro-humoral regulation in the body of fish, which affect the speed of development. The results of the study of the leading morphological and functional parameters of blood in fish in ontogenesis allowed identifying the adaptive capabilities of their body and assessing its functional status under the conditions of using technological factors (Table 1).

Table 1. Functional status of the body of carp fingerlings under the influence of a technological factor a when rearing before stocking, ($M \pm m$, $n = 50$)

Parameters	Carp <i>Cyprinus carpio</i>		Silver carp <i>Hypophthalmichthys hybrid</i>	
	Control group	Experimental group	Control group	Experimental group
Number of red blood cells, T/l	2.25 ± 0.031	2.36 ± 0.092	$2.29 \pm 0.039^*$	2.46 ± 0.055

Table 1. Continued

Parameters	Carp <i>Cyprinus carpio</i>		Silver carp <i>Hypophthalmichthys hybrid</i>	
	Control group	Experimental group	Control group	Experimental group
Haemoglobin content, g/l	83.20 ± 0.512	85.81 ± 1.201	82.23 ± 1.291	86.08 ± 1.380*
MCV, mkm ³	142.38 ± 2.308	161.97 ± 3.355	140.65 ± 1.953	158.50 ± 3.279***
MCH, pg	37.07 ± 0.414	36.64 ± 1.481	35.91 ± 0.675	35.15 ± 1.030
MCHC, %	24.56 ± 2.078	22.62 ± 0.119	23.39 ± 0.823	22.17 ± 0.334
Glucose, mmol/l	17.89 ± 0.625	18.10 ± 1.425	14.92 ± 1.218	15.03 ± 0.716
Total protein, g/l	17.97 ± 0.547	22.26 ± 1.016**	18.88 ± 0.704	21.88 ± 0.746*

Note: ^a – technological factor – feeding of carp with feed mixture + improved rearing conditions; *0.05 (P < 0.05); **0.01 (P < 0.01); *** 0.01 (P < 0.001)

Analysing the general picture of the leading parameters of homeostatic equilibrium in the fish body, there is a complete correspondence between the physiologically acceptable actual values of blood parameters that were studied for fish (Dehtiarov, 2001). However, the course of metabolic processes under the conditions of using the technological factor in the experimental group was more active in relation to the control parameters. This is actually evidenced by the higher indicators of the processes of haematopoiesis, synthesis, and accumulation of body weight in young carp and silver carp of the experimental group.

An increase in the content of red blood cells and hemoglobin in the blood of carp and silver carp confirms the activation of erythropoiesis systems in their body with an improvement in the respiratory surface of red blood cells. Each of the parameters corrects a certain functional system in the body, so the study of concentrations, analysis of the difference between experimental and control values provides an opportunity to more comprehensively consider the influence of the factors under study and evaluate their effectiveness in introducing young carp into the technological scheme of rearing.

As can be seen from the results presented in Table 1, a high level of blood oxygenation

can be achieved due to a larger number of red blood cells and an increase in the content of haemoglobin in them, that is, its transport. It is important to analyse and interpret the outlined processes at the morphological level. Therefore, the analysis of microcorpular blood parameters is informative and provides an opportunity to consider the parameters of haemoglobin concentration in cells, which will be discussed later in the paper.

Based on the data in Table 1, the indicators of the morphological and biochemical composition of blood are within the limits of physiological norms. In the experimental groups, there is an increase in red blood counts. Thus, the total number of red blood cells in the fish in the experimental group on silver carp significantly ($p < 0.05$) exceeded similar data in the control group by 7.4%; the haemoglobin content – by 4.7%, respectively, the hematocrit was also higher, the difference was 9.9%.

The study of morphological and functional parameters of carp blood provided the following results: the total number of red blood cells in the blood of fish that received additional biologically active components during feeding and were reared under the conditions of additional energy-saving elements in the technological map was higher by 4.9% with a higher hae-

moglobin concentration of 3.14% than in the control group. The functionality of metabolic processes also reflects the positive dynamics of microcirculatory parameters of blood: there is a certain correlation with the content of red blood cells, haematocrit, and one of the important buffer systems – haemoglobin content. The actual value exceeded the parameters in the control samples of silver carp by 12.7% ($p < 0.001$). Morphological and functional parameters according to the corpuscular index MCV in the blood of carp in the experimental group were 13.8% higher than in the control group.

The study of protein metabolism processes in the body of experimental fish complements the picture of the state of physiological and biochemical systems, in addition, it provides an opportunity to analyse the course of synthetic processes, the reserve of amino acids for protein synthesis in their body. Thus, in the experimental group, the total protein content exceeded the value in relation to the control group in the silver carp blood sample by 15.9% ($p < 0.05$). The study of this parameter in the carp group also showed higher values in the experimental group by 23.9% ($p < 0.01$) in relation to the control values. Analysis of blood glucose concentrations in experimental and control fish supplemented the study of metabolic processes under the influence of abiotic and biotic factors. Carbohydrate metabolism provides the level of energy resources in the body of hydrobionts, catabolic processes of carbohydrate metabolism. The concentration of glucose depended on the level of activity of fish against the background of the course of metabolic processes. In the experimental group, this parameter tended to have lower values relative to the control. The parameters did not exceed the maximum permissible physiological values, however, attention should be paid to the tendency to increase the concentration of glucose

in the blood of fish of the control group, which can identify as one of the options, the occurrence of a stressful state.

The parameters of metabolic processes in the body of carp and silver carp fingerlings were studied using one of the leading enzymatic complexes: alanine aminotransferase (ALT) and aspartate aminotransferase (AST). Since ALT and AST provide an opportunity to analyse the level of metabolic processes, in particular, protein, carbohydrate and lipid, the functioning of organs and systems in the fish body. The results of a study of protein metabolism activity, liver function, and resistance of young fish under the influence of a technological factor demonstrated that there was no significant difference between the groups. However, the level of AST according to the measurement results in the experimental groups significantly differed from the values in the control group ($P < 0.05$). The activity of the studied enzymes is widely used in the analysis of the functional status of the body as a whole, as a physiological and biochemical indicator of resistance to stress factors of various origins, and therefore, the adaptive capabilities of the fish body. The activity of the enzyme complex according to one of the marker parameters – liver catalase in the experimental group was higher than in the control group, both when sampling *Cyprinus carpio* and *Hypophthalmichthys hybrid*.

Notably, at the end of the growing period of hydrobionts, one of the important qualitative and quantitative parameters is the chemical composition of biological products. The analysis of the muscle part of carp and silver carp from the control and experimental groups is shown in Figure 2. One of the most important links is the quality of products delivered to the average consumer. In the context of scientific research concepts, the parameters of the functional status of the fish body ensure the

development of resistance of the body to the influence of abiotic and biotic factors, the growth and development parameters in ontogenesis, weight gain, output, etc. The analysis of the

biochemical composition of the muscle part of the selected carp samples showed a higher protein content of 4.5% and fat content of 6.4% in the experimental group.

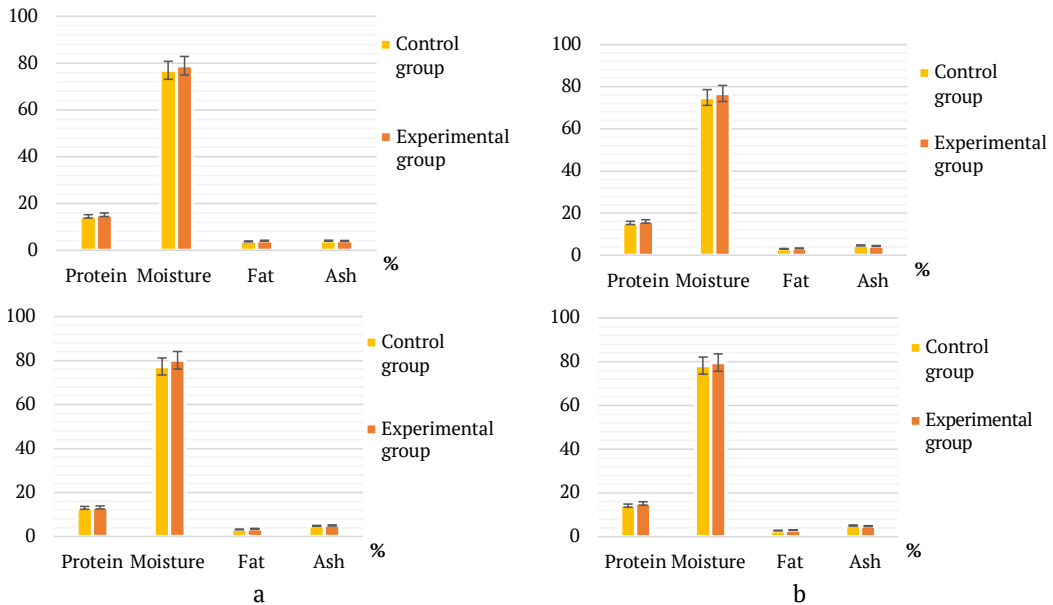


Figure 2. Analysis of the muscle part of *Cyprinus carpio* (a), *Hypophthalmichthys hybrid* (b) under the conditions of experimental research before and after stocking against the background of the introduction of the supplementary feeding of fingerlings ($M \pm m$, $n = 50$)

Source: developed by the author based on own research

The selected silver carp muscle samples also had higher actual values in the experimental group than in the control group. The difference was in protein content of 4.8% and fat content of 7.8%. Comparative analysis of the biochemical composition of the muscular part of carp and silver carp before stocking and after stocking by grown young fish showed a positive effect of introducing technological elements of supplementary feeding and improving aspects of fish cultivation.

It can be noted about the stimulating effect on the processes of growth and development of hydrobionts under the conditions of supplementary feeding in the early stages of

ontogenesis. Improving the parameters of the morphometric composition of blood also contributes to an increase in the growth rate of cyprinids. This stage of development is crucial for hydrobionts, since the potential for the future is being developed. In particular, the qualitative and quantitative parameters of products in aquaculture directly depend on the conditions of growing and feeding hydrobionts, and not just on their genetic potential.

Summarising the results of the experimental study, it is advisable to focus on the stimulating, corrective effect of the feed mixture when feeding young carp at the early stages of ontogenesis. The non-aggressive effect of each

of the elements contributes to the gradual restructuring of metabolic processes in the carp body, which has an important physiological and biochemical significance. Under the conditions of a mismatch of action and reaction to abiotic and biotic factors, stress reactions can occur in hydrobionts. It was the combination of all the components in the feed mixture that provided a positive effect. It is known that certain components, when ingested by aquatic organisms, also have a catalytic effect.

The available literature contains information reflecting the effectiveness of using microalgae and protein components in feeding the general diet. Such substances, when ingested, contribute to the restructuring of individual-level reactions, protein, carbohydrate, and lipid metabolism (Kovalenko & Polishchuk, 2018; Bekh *et al.*, 2020; Hryhorenko *et al.*, 2021). However, against the background of the use of alternative energy sources, a successful combination of all the components for feeding carp presented in this paper was investigated for the first time.

S. Nagappan *et al.* (2021), analysing the effect of microalgae on the rate of development of hydrobionts, note that a high concentration of microalgae in feed can contribute to the opposite effect – inhibition of fish growth rate. However, the researchers practised including *Arthospira* biomass in fish meal. But the method proposed by the authors of this study provides for a separate use of the manufactured feed mixture in the general economic diet. This creates the possibility of symbiosis of the proposed biologically active substances with the effect of synergy, and not vice versa. In addition, there are judgments of some researchers, supported by experimental studies, where the effect of transformation of enzymatic activity in fish was obtained under conditions of prolonged and uneven use of microalgae for feeding as an additive (Dallaire *et al.*, 2007). At the

same time, emphasis is placed on the method of microalgae cultivation, a certain type and ratio of the proportion of components of natural feed when feeding hydrobionts. The proposed method and ingredients of the feed mixture in this sex do not affect the leading indicators, in particular morphological and functional parameters of blood and enzymatic activity in carp, which is confirmed by the results obtained. In the context of a comprehensive study of the effectiveness of using natural feed to increase the resistance of fish organism, metabolic processes, enzymatic activity, and immunomodulatory effect, it is possible to note the positive effect of such components on metabolic processes in fish. The *Spirulina platensis* and *Isochrysis galbana* biomass function as prebiotics: when they enter the body, they contribute to the development of beneficial bacteria (Dineshbabu *et al.*, 2019). In numerous studies, it is mainly represented by monocomponent mixtures. Under the conditions of the proposed method of increasing the functional activity of the fish body, several elements occur, in particular, biologically active substances of humic nature, microalgae *S. Platensis*. Thus, there is a complex effect of such composites. Accordingly, the effect has a wider range, covering neuro-humoral locus processes in the fish body.

The information presented in the reviews and research papers mentions low fermentation and assimilation of microalgae such as *Chlorella sp.*, *Nannochloropsis sp.*, which is explained by the presence of non-starchy substances, rather rigid cell walls (Skrede *et al.*, 1998). Regarding *S. Platensis*, it can be noted that it is included in the feed mixture in combination with biologically active substances of humic nature. In turn, humic substances have a number of properties that support other components, after entering the body, individual processes are restructured, activated,

and corrected. Therefore, the additive proposed in this paper to increase the viability of young hydrobionts has a number of advantages among already known composites.

The experimental results indicate that microalgae in the composition of supplements, due to their high protein content, can be an alternative to fish meal or a supplement to adjust the nutritional qualities of ingredients in the general fish diet (Abdulrahman *et al.*, 2018). There are positive results on the example of microalgae *Chlorella* regarding a significant increase in the parameters of development in carp ontogenesis. Q. Zhang *et al.* (2014) used 0.8% chlorella, which increased the fish body weight in the experimental group from 29.90 ± 0.08 to 63.75 ± 1.96 g with WG 33.85 ± 1.96 g, which was higher than in the control group ($P < 0.05$). At the same time, previous studies have shown that *Chlorella* can participate in the regulation of adaptive and innate immunity, and increase the level of immunoglobulins and enzymatic activity in the carp body (Zhang *et al.*, 2014). Undoubtedly, each element of microalgae has typical characteristics, and is active and effective under certain conditions of cultivation, processing, and introduction to the general economic diet. However, the results of experimental studies present an unambiguously positive effect on the functional status of the body of hydrobionts, in particular, physiological and biochemical parameters, indicators of the rate of development, and the yield of hydrobionts.

The results of such experiments on the correction of feeding conditions are often ambiguously interpreted, since the “mixing” effect of other components and additives to the diet occurs precisely in conditions of heterogeneity of the use of similar components by other researchers. Therefore, considering this effect, it is advisable to annotate the results of the use of humic substances and spirulina with

positive dynamics in the context of optimising the conditions for supplementary feeding and growth of aquaculture objects.

Conclusions

Summing up the whole complex of results obtained, it can be noted that the body of hydrobionts is a complete functional system that shows a certain reaction to each factor. The parameters of the development rate of fish are adjusted with the main physiological and biochemical processes in their body. Neurohumoral regulation of all vital functions reacts reactively to the intake of biologically active substances of various origins. The results obtained demonstrate positive indicators of improvement in fish resistance to abiotic and biotic factors. Annual stocking programmes will be effective if viable carp juveniles are used in polyculture. Based on generally accepted classical methods of growing hydrobionts, it is possible to improve individual links of the technological process. The introduction of such elements of the feed factor and the element of technological operation of basin models in the context of the filtration system and an additional element of alternative energy sources contribute to the achievement of the goals set. Young fish have a higher resistance to the negative effects of abiotic and biotic factors. In particular, the erythrocyte blood picture reflects the course of positive functional processes in the body of fish of the experimental group. As a result, the effective use of the potential capabilities of the body of experimental carp youth and the best respiratory function was noted, which positively affects the development processes, body weight accumulation, and resistance to various factors. The development potential positively corrects the physiological and biological status, growth rate, and output.

Improvement of metabolic processes and increase in the parameters of carp development occurred as a result of transformations and morpho-metric parameters of fish blood. In particular, the total number of red blood cells in the group where the technological factor under study and its direct impact on the functional status of the organism exceeded the actual values of the control parameters. In turn, this was reflected in the corpuscular parameters of the blood, the concentration of haemoglobin. Consequently, synthetic processes in the body of fish of the experimental group were more active and effective in relation to carp from the control group. Since the functional system maintains its own viability and activity due to consistent action and the influence of each of the parameters that form complex processes, it is possible to assume exactly the corrective effect of the feed mixture. By a certain activation

of metabolic processes, increasing the synthesis of complex and simple compounds in the body of hydrobionts, stabilisation, increased resistance and development occurred in fish in the experimental group.

Based on the results of the positive impact of the studied factor on improving the viability of young fish, the authors note the line of future research that will provide a deeper understanding of the effectiveness. Consequently, histological studies of biological material from the control and experimental groups will complement the understanding of the mechanism of action of the feed mixture under study.

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None.

Conflict of Interest

None.

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Фізіолого-біохімічні аспекти організму корокових за умов підвищення їх життєздатності при зарибленні водою

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Анотація. Актуальність дослідження зумовлена визначальною роллю етапу раннього розвитку в онтогенезі молоді риб при формуванні потенціалу їх швидкості росту. Фізіолого-біохімічний статус організму визначає адаптаційні можливості гідробіонтів, тому одним із векторів поліпшення параметрів розвитку було обрано використання біологічно активних речовин при підрощенні. Метою дослідження було визначення ефективності впровадження технологічних елементів (підгодівлі, підрощення) на ранніх стадіях онтогенезу молоді риб. Дослідження ґрунтувалось на теоретичних (аналіз, синтез, порівняння, моделювання) експериментальних, лабораторних методах, прийнятих у рибогосподарських, фізико-хімічних дослідженнях. В ході дослідження проводився клінічний огляд риб, контроль темпів росту, масонакопичення, рівня виживання, фізіологічного стану. Результати демонструють підвищення життєздатності молоді риб, активацію метаболічних процесів, поліпшення морфо-функціональних параметрів крові. Середня маса цьоголіток перевищувала параметри в контрольній групі по коропу на 3,5 % та по товстолобику на 3,8 %. Загальна кількість еритроцитів дослідної групи по товстолобику була вище за контроль на 7,4 % ($p < 0,05$), вміст гемоглобіну – на 4,7 %, гематокрит – 9,9 %. Загальна кількість еритроцитів в крові коропа дослідної групи була вище на 4,9 %, вміст гемоглобіну – на 3,1 %, ніж в контролі. В експериментальній групі, вміст загального білку перевищував значення по відношенню до контрольної групи по товстолобику на 15,9 % ($p < 0.05$), по коропу – на 23,9 % ($p < 0.01$). Ферментативна активність в дослідній групі була вищою щодо контролю. Запропонований спосіб підгодівлі сприяє збільшенню швидкості росту риб. Практична цінність дослідження полягає у сприянні поліпшенню якісних та кількісних параметрів, зокрема, біохімічного складу м'язової частини по коропу та по товстолобику у пробах в експериментальній групі в порівнянні з контрольними значеннями

Ключові слова: функціональний статус; гідробіонти; технологічні елементи; резистентність; підрощення



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Analysis of genotyping features of bovine cattle individuals at the CSN2 locus using ACRS-PCR methods

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Abstract. In the context of solving the problem of obtaining high quality dairy products from livestock, the issue of determining the type of beta-casein (A1 and A2) in the protein fraction of milk becomes essential. Purpose – to analyse the use of ACRS-PCR methods for differentiation of A¹ and A² alleles of bovine beta-casein locus. Genotyping features were analysed using the artificially created restriction site polymerase chain reaction method utilising TaqI and DdeI restriction endonucleases. The electrophoretic distribution of DNA fragments in agarose gels of various concentrations was used to analyse restriction patterns. Based on the results of bioinformatic analysis of the nucleotide reference sequences of the experimental fragment of the beta-casein gene, it was found that the primer system for the ACRS-PCR DdeI method is characterised by higher parameters of flanking efficiency of the target DNA site compared to the ACRS-PCR TaqI system due

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to significantly greater effectiveness of hybridisation of oligonucleotides on the target DNA. Based on the results of laboratory tests of both methods, it is proposed to use an additional procedure for analysing the fluorescence intensity of individual elements of restriction patterns, which allows reducing the number of false genotyping that occurs in both cases (based on the results of using both methods) due to the appearance of non-specific amplification/restriction fragments within the size of target restrictions. The application of the ACRS-PCR DdeI method provides more differentiated patterns of the corresponding genotypes in agarose gel compared to the ACRS-PCR TaqI method, but leads to higher material costs for conducting research. These disadvantages of using primer systems for ACRS-PCR of the beta-casein locus determine the relevance of developing alternative methods for typing A¹ and A² alleles which include allele-specific PCR. The use of results is promising for solving the problems of genotyping cattle individuals of different breeds by A¹ and A² alleles of the beta-casein locus

Keywords: polymorphism; restriction; electrophoresis; allele; amplification

Introduction

High quality of dairy products is the ultimate goal of practical work in cattle breeding. As noted by S.A. Ibrahim *et al.* (2021), one of the main factors that negatively affect the consumption of milk and dairy products is lactose intolerance syndrome, which is believed to be caused primarily by genetic factors and is associated with insufficient lactase activity. However, as the results of numerous studies have shown, according to the review of S. Pal *et al.* (2015), the negative effects of milk consumption are associated not only with lactose, but also with individual protein fractions.

According to M. Macedo *et al.* (2020), the total protein fraction of milk consists of 80% casein fraction, with the largest being the beta-casein fraction, which reaches 40% of the total amount. As indicated by Bisutti *et al.* (2022) and De Vitte *et al.* (2022), in the context of the negative effects of milk consumption, the focus is on beta-casein, some variants of which are associated with the manifestation of various diseases. According to the study by S. Kay *et al.* (2021), a special substance, 7 beta-casomorphine, which is very closely related to beta-

casein, is involved in the development of pathological effects from the use of dairy products.

A. Summer *et al.* (2020) report that casomorphin is a short peptide consisting of 7 amino acid residues. The functions of this peptide include the ability to model the effect of a number of different hormones of the gastrointestinal tract and central nervous system. It has an opioid effect that is directly related to the manifestation of allergic reactions. The situation is complicated by the fact that casomorphine is able to pass through the blood-brain barrier, which is of greatest importance for children.

According to C. Sebastiani *et al.* (2020), beta-casein molecule can exist as several variants that differ in certain amino acid residues in the molecule – A¹ and A² forms of beta-casein. The differences between the two types of molecules are in one amino acid (only for A¹ and A² forms). As indicated in the paper by Thiruvengadam *et al.* (2021) in A² this is proline at position 67, and in A¹ – histidine. The presence of histidine at position 67 determines the entire further fate of the molecule. When A¹ beta-casein enters the gastrointestinal tract, cleaving occurs at the

position containing histidine, which leads to the formation of beta-casomorphins. In turn, this is not happening in the case of type A² beta-casein. Thus, the consumption of milk containing beta-casein type A¹ leads to the formation of beta-casomorphins, which causes various pathological effects, the most prominent manifestation of which is digestive system disorders.

Understanding the nature of a point mutation in the beta-casein gene that determines the existence of allelic variants A¹ and A², which enabled the creation of effective tools for its detection. In the last few years, a number of different molecular genetic research methods are used to differentiate A¹ and A² alleles. As stated by C. Sebastiani *et al.* (2022), M. Sodhi *et al.* (2021) and Ivankovic *et al.* (2021), despite the attractiveness of modern sequencing methods, which are also used for typing cattle individuals at the beta-casein locus, the most common are methodological approaches for using certain restriction endonucleases. However, despite the widespread use of methodological approaches based on the use of restriction endonucleases, the analysis of technical features of typing cattle individuals was rather neglected (in a comparative aspect).

Thus, the purpose of this study is to analyse the features of genotyping of cattle individuals at the *CSN2* locus (alleles A¹ and A²) using ACRS-PCR methods.

Literature Review

According to Yamada *et al.* (2021), methods for detecting allelic variants of the beta-casein gene were developed, which use not just analyse a product – milk, but directly analyse the producer – in this case, a cow. One of the main obstacles to the effective genotyping by an experimental mutation using one of the most common genotyping methods, PCR-RFLP, or restriction analysis, is the fact that the SNP (point

mutation) that determines the presence of variants A¹ and A², is not located at the restriction site for any endonuclease. The lack of variations in the restriction site makes it impossible to use PCR-RFLP, which necessitates the development of alternative methods. As noted by Smiltina *et al.* (2018) and Antonopoulos *et al.* (2021), one of the most common alternative methods for detecting various allelic variants *CSN2* gene is ACRS-PCR.

According to the study by Pauciuolo *et al.* (2021), ACRS-PCR (artificially created restriction site polymerase chain reaction) is based on the use of restriction endonuclease, but, unlike classical PCR-RFLP, the site for the enzyme is present only in the amplicon, and not in the original fragment of the gene. Dąbrowski *et al.* (2019), report that the creation of an artificial restriction site in an amplicon occurs through the use of a special primer in a standard pair, which at the 3' end contains a "false" nucleotide (usually at position 2 of the 3' end), which, in the case of one of the alternative alleles, forms a restriction site during amplification. It is the presence of a mismatch nucleotide in combination with the copied sequence of one of the alleles that leads to the formation of a restriction site in the amplicon. After amplification, a standard restriction analysis is performed, followed by electrophoretic separation of fragments in the gel. The method allows genotyping of cattle individuals at the beta-casein locus with high success.

One of the first modifications of this method was proposed by S. Lien *et al.* in 1992 based on the use of TaqI as a restriction endonuclease. In the following years, a number of modifications appeared, one of the most common is the method developed by McLachlan (2006), based on the use of DdeI restriction endonuclease. The variability of the effectiveness of the above methods underlies the need to search for

new and optimise existing methods for typing beta-casein alleles, which is particularly important in the context of genotyping cattle individuals to solve commercial issues.

Materials and Methods

The research was conducted in the laboratory of molecular genetic research of the Department of animal biology of the National University of Life and Environmental Sciences of Ukraine.

To investigate the effectiveness of genotyping of cattle individuals by A¹ and A² alleles, DNA samples from cows of the Ukrainian Black-and-White dairy breed were used as a model object of the beta-casein locus. Hair follicles were used as a source of biological

material. DNA isolation was performed using a commercial set of reagents “DNA-sorb-B” (“AmpliSens”).

Genotyping of experimental cattle breeds was performed using ACRS-PCR methods (2 methods – using TaqI and DdeI restriction endonucleases), the ACRS-PCR method allows creating an artificial restriction site in the amplicon, which, in turn, allows using appropriate restriction endonucleases for typing individuals. The authors used ARRIVE instructions as a checklist during experiments. Certain primer systems were used to amplify a fragment of the seventh exon of the beta-casein gene. The nucleotide structure and names of primers are shown in Table 1.

Table 1. Method, labelling, and nucleotide structure of the primers used

Method	Primer	Source	Nucleotide sequence
ACRS-PCR (DdeI)	DdeI F	(McLachlan, 2006)	cctttttccaggatgaactccagg
	DdeI R		gagtaagaggaggatgttttgggaggctct
ACRS-PCR (TaqI)	TaqI F	(Lien <i>et al.</i> , 1992)	cctgcagaattctagtctatcccttccctgggccatcg
	TaqI R		gagtcgactgcagatttcaacatcagtgagagtcaggctctg

The following amplification programmes were used to amplify the experimental fragment of the beta-casein gene: 1 cycle – denaturation at 94°C, 5 min.; 35 cycles – denaturation at 94°C, 30 s, annealing (60°C for ACRS-PCR TaqI and 56°C for ACRS-PCR DdeI) 30 s, elongation – 72°C, 30 s.

Polymerase chain reaction (PCR) was performed using a commercial DreamTaq PCR Master Mix reagent kit (ThermoScientific). The volume of the final reaction mixture was 10 µL, the primer concentration was 0.2 µM.

Size of restriction fragments in the case of ACRS-PCR DdeI (restriction site C↓TNAG) is 121 bp for A¹ allele; 86 and 35 bp for the A² allele.

Size of restriction fragments in the case of ACRS-PCR TaqI (restriction site T↓CGA) is 251 bp for A² allele; 213 and 38 bp for the A¹ allele.

For the purpose of electrophoretic separation of amplification/restriction products, a 3% agarose gel for the ACRS-PCR DdeI method and a 1.5% gel for the ACRS-PCR TaqI method were used. Restriction products were separated in agarose gels at a voltage of 150 V for 40-60 minutes.

Visualisation of DNA fragments in the gel was performed using ethidium bromide in the ultraviolet spectrum (312 nm). The molecular weight marker GeneRuler 50 bp (Thermo Scientific) was used to determine the size of the amplification/restriction fragments.

The online Nucleotide Blast toolkit was used to analyse nucleotide sequences. To determine the amplification efficiency when using bioinformatic analysis, the X14711.1 bovine beta-casein gene nucleotide sequence was used as a reference.

Results and Discussion

A comparative analysis of the effectiveness of ACRS-PCR methods was carried out, considering the bioinformatic analysis of nucleotide sequences in the GenBank database.

Based on the results of bioinformatic analysis, it was found that the ACRS-PCR DdeI prim-

er system (primer sequences are given above) is more preferable in terms of hybridisation efficiency (total number of matches according to Watson-Crick nucleotide interaction) with the reference sequence compared to the ACRS-PCR TaqI system. The analysed fragment of the beta-casein gene is shown in Figure 1.

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7981 attataactg gattatggac tcaaagattt gttttccttc tttccaggat gaactccagg
8041 ataaaatcca cccctttgcc cagacacagt ctctagtcta toccttccct ggaccocatc
8101 ataacagcct ccacaaaaac atccctcctc ttactcaaac cctgtggtg gtgcgcgctt
8161 tccttcagcc tgaagtaatg ggagtctcca aagtgaagga ggctatggct cctaagcaca
8221 aagaaatgcc cttccctaaa tatccagttg agccctttac tgaaaagcag agcctgactc
8281 tcactgatgt tgaaaatctg caccttcctc tgcctctgct ccagtcttgg atgcaccagc
  
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Figure 1. Fragment of the beta-casein gene that is flanked by the use of appropriate primer systems
Note: (Bovine beta-casein gene. GenBank: X14711.1 as amended). Hybridisation sites for ACRS-PCR (DdeI) primers are marked with rectangles, and for ACRS-PCR (TaqI) – in grey. A target mutation C>A is indicated in bold (position 8101 “a”)

The efficiency of forward and reverse primer hybridisation (ACRS-PCR DdeI) was 100%, excluding the nucleotide mismatch (position 8105 C > G, Figure 1). In turn, for the ACRS-PCR TaqI method, the hybridisation efficiency of forward and reverse primers was 55 and 82%, respectively. In each case, the presence of a kind of “tail” of nucleotides was observed (positions 8162-8171 and 8303-8308, Figure 1), which can lead both to a decrease in PCR efficiency and

to the formation of non-specific amplification products due to suboptimal temperature conditions for annealing primers on the DNA matrix. The established features are also reflected in the electrophoregrams.

Figure 2 shows an electrophoregram of restriction products of the seventh exon of the beta-casein gene using TaqI. Individuals with all possible genotypes were found in the experimental group: A¹A¹, A¹A², and A²A².

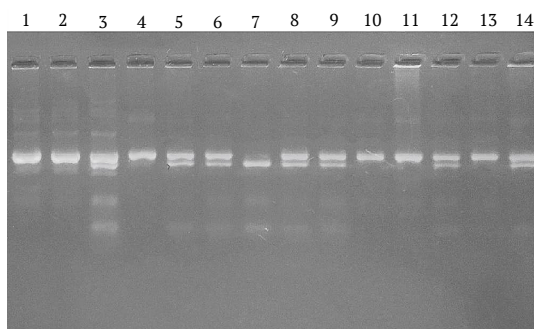


Figure 2. Results of typing of cattle individuals using the ACRS-PCR (TaqI) method
Note: 1 – amplicon; 2, 4, 10, 11, 13 – A²A²; 3, 5, 6, 8, 9, 12, 14 – A¹A²; 7 – A¹A¹

Genotype A^1A^1 is represented on the electrophoregram by fragments 213 and 38 bp; A^1A^2 – 251, 213, and 38 bp; A^2A^2 – 251 bp. The presence of non-specific amplified DNA fragments on the electrophoregram is considered undesirable phenomena for several reasons. First, non-specific amplified fragments can potentially contain a restriction site for the endonuclease used, which will significantly complicate both the effectiveness of the reaction and the interpretation of the resulting patterns. Second, the size of non-specific fragments may coincide with the restriction patterns for the target object. In the case of using the ACRS-PCR TaqI method, this pattern is observed (Figure 2, samples 1-4). Optimisation of the PCR protocol (first of all, the temperature regime of primer annealing) allows reducing the formation of non-specific fragments to a minimum. However, in the case of the pronounced disadvantages of the primer system mentioned above, the formation of non-specific products still occurs. This leads to the need to analyse the intensity of the fluorescence of fragments in a comparative aspect with the target restrictions. Target restriction fragment (allele A^2 , size 251 bp) has a much higher luminous intensity in the ultraviolet spectrum (ethidium bromide is used as an intercalating dye) due to the larger amount

of DNA. Based on the analysis of the fluorescence intensity of fragments, it is possible to distinguish between “true” and “false” bands on the electrophoregram. However, the situation significantly worsens as a result of a general decrease in the amplification efficiency. In this case, it is very difficult to distinguish between target and non-specific products, which further leads to difficulties in genotyping individuals.

In some samples, it is possible to observe the formation of non-specific fragments that have a size within the target restrictions, which can lead to erroneous typing of individuals as heterozygous. In this case, it is necessary to analyse the fluorescence intensity of various fragments of the pattern. The presence of significant shortcomings in the above-mentioned method (the impossibility of unambiguous and error-free identification of various genotypes in the absence of additional procedures) leads to the need to develop new methods for typing by alleles of the beta-casein locus. Figure 3 shows a photo of the electrophoregram of the results of typing bovine individuals using the ACRS-PCR DdeI method. The electrophoregram shows individuals with all possible genotype variants: A^1A^1 , A^1A^2 , and A^2A^2 . Genotype A^1A^1 shown on the electrophoregram as a single fragment, measuring 121 bp; A^1A^2 – 121, 86, and 35 bp; A^2A^2 – 86 and 35 bp.

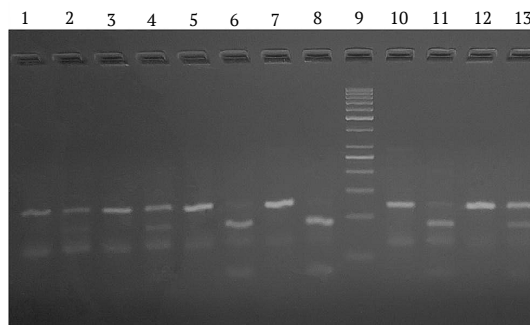


Figure 3. Results of typing of cattle individuals using the ACRS-PCR (DdeI) method

Note: 1 – amplicon; 3, 5, 7, 10, 12 – A^1A^1 ; 2, 4, 13 – A^1A^2 ; 6, 8, 11 – A^2A^2 ; 9 – molecular weight marker GeneRuler 50 bp

The ACRS-PCR method, using DdeI restriction endonuclease, has proven itself quite well as a routine tool for typing cattle individuals at the beta-casein locus, but despite all the advantages, it also has a number of disadvantages, some of which lead to errors in genotyping. The main disadvantage of this method is the need to use DdeI restriction endonuclease, which leads to an increase in time and material costs. In a fairly large number of cases, the presence of non-specific fragments on the electrophoregram was noted, which, given the rather small size of the original amplicon (121 bp), significantly hinders the identification of the A^2 allele and the heterozygous genotype A^1A^2 . This occurs based on the results of the presence of a non-specific fragment in the identification zone of the A^2 allele in the restriction pattern. The presence of a non-specific fragment that is sufficiently close to the restriction (86 bp) may be a factor in misinterpreting this genotype as heterozygous, which may lead to a decrease in the number of identified homozygous for the A^2 allele, individuals in the population under study. An additional factor that significantly complicates the identification of alleles is the need to analyse the fluorescence intensity (staining) of restriction fragments. In the case of the absence of inhibitors in the PCR mixture, the intensity of staining of the fragment of the A^2 allele must be smaller than that of a fragment of the A^1 allele, due to a smaller amount of DNA (amplicon of the A^2 allele contains a restriction site for DdeI). Ignoring these facts on the part of researchers can lead to confusion in the analysis of genotypes in the case of insufficient restriction endonuclease activity.

As follows from the results of research and analysis of these electrophoregrams, the detection method based on the use of DdeI restriction endonuclease is more convenient and effective for the needs of cattle typing compared

to the TaqI method. The results of experimental studies fully confirm the conclusions that were made during the bioinformatic analysis (given above). The greater efficiency of primer hybridisation on the target DNA sequence, which was demonstrated by analysing the correspondence of the nucleotide structure of the study objects (Watson-Crick interactions between the forward and reverse primer sequences and the target DNA), resulted in greater PCR efficiency. First of all, by increasing the specificity of the reaction, and secondly, by increasing the efficiency of amplification. The increase in the specificity of the reaction is directly caused by the structural features of the oligonucleotides used, which, in the case of ACRS-PCR DdeI, hybridise with the experimental fragment as efficiently as possible. In turn, unambiguous positioning of the primer on the total genomic DNA (flanking the experimental fragment of the genome) leads to a high efficiency of the amplification itself.

Despite the above advantages, the ACRS-PCR method for using DdeI restriction endonuclease has certain disadvantages. In some cases, the formation of non-specific reaction products is observed. At the same time, the presence of non-specific DNA fragments is recorded in the zone that overlaps with the existing restriction fragments, which can potentially affect the effectiveness of typing (to increase the number of heterozygous individuals in the experimental group of animals). The use of DdeI restriction endonuclease leads to a significant increase in the cost of conducting research, which, along with the standard disadvantages of the ACRS-PCR method that include the need for additional stages of analysis (requires significant time and reagents), determines the relevance of developing alternative methods for typing A^1 and A^2 alleles, the use of which would not have the above-mentioned disadvantages,

which was proposed by a number of researchers in the form of allele-specific PCR techniques.

The allele-specific PCR (AS-PCR) method is devoid of additional costs associated with restriction analysis, although it requires setting up 2 amplification reactions (for each of the alleles). In addition, as practice shows, the AS-PCR method also has disadvantages caused by the hybridisation features of primers that differ by 1 nucleotide at the 3' end, which can also affect the accuracy of genotyping. If PCR protocols are optimised, this method shows fairly accurate results. However, despite the existing advantages, the allele-specific PCR method requires compliance with specific requirements for the accuracy of maintaining temperature conditions with an amplifier (thermal cycler). Any variability or technical impossibility of using certain temperatures during different PCR cycles leads to non-specific amplification of alleles, which can lead to errors in genotyping (first of all, to an increase in the total number of heterozygous individuals in the sample). Therefore, in almost every case, for genotyping different targets, it is necessary to carefully adapt the amplification protocols of experimental fragments, provided that an additional method of individual typing is used. In the vast majority of studies using the allele-specific PCR method, the authors actually ignore the need to optimise protocols and use the amplification programmes available in other literature sources without any modifications (Rahimi *et al.*, 2015).

In turn, the use of a bioinformatic approach, which is based on the analysis of the GenBank nucleotide sequence database, allows not only identifying specific primer hybridisation sites on the target DNA and the size of the flanked fragment, but also establishing potential non-specific hybridisation sites, which can significantly help in optimising PCR protocols. In both cases (ACRS-PCR TaqI and DdeI), the

results of the analysis of the reference nucleotide sequence (X14711.1) established a high specificity of the selected primer systems. According to the results of the analysis, only two potential (additional to the target) variants were identified for the ACRS-PCR TaqI primer system, while they were completely absent for ACRS-PCR DdeI. The potential possibility of amplification of non-specific fragments during PCR along with the target fragment of the genome led to the appearance of additional DNA bands (false bands) on the electrophoregram.

In addition to the general information "contamination" of the image, the presence of non-specific fragments significantly complicates the process of restriction of amplicons, since additional amplified sections of DNA can potentially contain a restriction site for the restriction used, which leads not only to a large number of different fragments, but also to a significant decrease in the effectiveness of the restriction reaction. All of the above negatively affects the quality of typing, so, if possible, any potential non-specific hybridisation of primers in other parts of the genome should be avoided (this is especially true in the case of non-specific annealing in different parts of the genome that coincide with the target for the animal species). In view of the above, it becomes clear that PCR protocols need to be optimised to prevent nonspecific amplification. The best approach is to use the maximum possible (highest possible) annealing temperature, as well as (which is less effective) variations in the duration and number of amplification cycles. The results of the bioinformatic analysis are confirmed by the results of electrophoretic separation of restriction fragments, which is shown in Figures 2 and 3 – in the case of the ACRS-PCR TaqI method, additional fragments are available on the electrophoregram, while when using the ACRS-PCR DdeI method, there are significantly less

non-specific amplification/restriction products. Thus, the use of bioinformatic analysis of amplification efficiency is fully confirmed by direct laboratory studies on typing cattle individuals at the experimental locus.

Given the above, it would be advisable to use AS-PCR as the main (simpler and less expensive) method for conducting routine studies of beta-casein locus polymorphism. In turn, to resolve controversial issues related to the accuracy of genotyping, it is necessary to use an alternative method based on ACRS-PCR, in particular, for the use of DdeI restriction endonuclease.

Additional aspects of the problem of animal typing by A¹ and A² alleles of the beta-casein gene refer to confusion regarding the use of certain terminology. The methods mentioned in this paper relate specifically to ACRS-PCR, which is caused by the fact that there is no restriction site for any endonuclease in the target fragment (which contains a polymorphic nucleotide). Accordingly, the use of the ACRS-PCR method (for both DdeI and TaqI) leads to the formation of an artificial restriction site in amplicon (amplified fragment), and not in the experimental fragment of the gene (genome). Therefore, the use of the PCR-RFLP designation, in this case, is completely incorrect, which, unfortunately, is not considered by some researchers (Pandey *et al.*, 2020; Vougiouklaki *et al.*, 2020; Mokhnachova, 2021).

Conclusions

The effectiveness of ACRS-PCR methods (for the use of DdeI and TaqI restriction endonucleases) for typing cattle individuals by the beta-casein locus (typing alleles A¹ and A²) was analysed. According to the results of bioinformatic analysis of nucleotide reference sequences (X14711.1) of the experimental fragment of the beta-casein gene, it was found that the primer system for the ACRS-PCR DdeI method

is characterised by higher parameters of flanking efficiency of the target DNA section compared to the ACRS-PCR TaqI system, due to significantly greater effectiveness of hybridisation of oligonucleotides on the target DNA and almost the complete absence of non-specific amplification products. The results of the theoretical analysis are fully confirmed by laboratory studies on animal typing at the beta-casein locus by two methods. Based on the results of laboratory tests of both methods, it is proposed to use an additional procedure for analysing the fluorescence intensity of individual elements of restriction patterns, which allows reducing the number of false genotyping that occurs in both cases (based on the results of using both methods) due to the formation of non-specific amplification/restriction fragments within the size of target restrictions. Considering these shortcomings of primer systems (ACRS-PCR) for typing cattle individuals at the beta-casein locus, it is advisable to consider alternative methods of genotyping, in particular, the allele-specific PCR method, which, despite certain features of its application, is quite promising for conducting routine large-scale studies in cattle populations of different breeds. In addition to all of the above, ACRS-PCR methods based on the use of DdeI and TaqI restriction endonucleases can be very useful for resolving controversial issues as a reference verification method for typing in order to avoid errors in genotyping cattle individuals by the beta-casein locus. The use of ACRS-PCR methods for typing cattle individuals by allelic variants of the beta-casein locus, both as the main method of typing and for solving technical problems in PCR formulation, allows not only conducting genetic and population studies of different cattle breeds of cows, but also serves as a reliable tool for further implementation of methodological approaches to marker-associated selection (MAS) in dairy

cattle breeding. The use of the proposed methodological approaches allows effectively and accurately differentiating different genotypes (A¹A¹, A¹A², and A²A²) by the beta-casein locus, conducting individual typing of cattle individuals, and selecting animals with the desired genotype for use in further breeding to create herds of cows producing A2 Milk. Other promising areas include the development of alternative

methods for typing cattle individuals by allelic variants A¹ and A² of beta-casein locus using ACRS-PCR as a reference method.

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Conflict of Interest

None.

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Аналіз особливостей генотипування особин великої рогатої худоби за локусом *CSN2* за використання методів ACRS-PCR

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Анотація. У контексті вирішення проблеми одержання високої якості молочної продукції скотарства питання визначення типу бета-казеїну (A1 та A2) у білковій фракції молока набуває суттєвого значення. Мета роботи – проведення аналізу використання методів ACRS-PCR для диференціювання алелів A¹ та A² локусу бета-казеїну великої рогатої худоби. Аналіз особливостей генотипування проводили за використання методу ACRS-PCR (Artificially Created Restriction Site Polymerase Chain Reaction) із застосуванням ендонуклеаз рестрикції TaqI та DdeI. Для аналізу рестрикційних патернів використовували електрофоретичний розподіл фрагментів ДНК в агарозних гелях різних концентрацій. За результатами біоінформаційного аналізу нуклеотидних еталонних послідовностей дослідного фрагменту гену бета-казеїну з'ясовано, що праймерна система для методу ACRS-PCR DdeI характеризується більш високими параметрами ефективності фланкування таргетної ділянки ДНК у порівнянні з системою ACRS-PCR TaqI внаслідок значно більшої результативності гібридизації олігонуклеотидів на ДНК-мішені. За результатами лабораторних випробувань обох методів запропоновано використання додаткової процедури аналізу інтенсивності флуоресценції окремих елементів рестрикційних патернів, що дає можливість зменшити кількість помилкових генотипувань, що виникають в обох випадках (за результатами використання обох методів) за рахунок утворення неспецифічних ампліфікаційних/рестрикційних фрагментів у межах розміру цільових рестриктів. Застосування методу ACRS-PCR DdeI дає можливість отримати більш

диференційовані патерни відповідних генотипів в агарозному гелі у порівнянні з методом ACRS-PCR TaqI, але при цьому призводить й до більших матеріальних витрат на проведення досліджень. Зазначені недоліки використання праймерних систем для ACRS-PCR локусу бета-казеїну, визначають актуальність розробки альтернативних методів типування алелів A¹ та A² до яких належить алель-специфічна ПЛР. Використання результатів досліджень є перспективним для вирішення проблем генотипування особин великої рогатої худоби різних порід за алелями A¹ та A² локусу бета-казеїну

Ключові слова: поліморфізм; рестрикція; електрофорез; алель; ампліфікація

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Analysis of the raw material base for pectin production

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Abstract. The addition of pectin to food products is important because this natural polysaccharide plays a key role in improving the quality and stability of the product, it allows for high-quality preservation of products that have a long shelf life, which is important for the health and well-being of consumers. The purpose of the study is to investigate the main raw materials of plant origin for the synthesis of pectin, which can be used as a promising raw material for food industry enterprises in Ukraine. The study was carried out using various methods of analysis, a thorough comparative analysis of papers by Ukrainian and foreign researchers, which are published in the scientometric databases Scopus, Web of Science, Journal Citation Reports, Scimago Journal & Country Rank, and Google Scholar. Based on the results of analytical studies, the main raw materials used for the production of pectin and pectin-containing pastes were analysed, and the main problems of the production process were identified. It has been found that adding pectin to food products can have a significant number of benefits: increasing the viscosity of the product, which is useful for creating a thick texture of the product; increasing the resistance of the product to heat treatment, reducing the risk of product separation or quality degradation; increasing functionality; introducing it into products can help improve the consistency and appearance of the product, add taste and color properties, and reduce the amount of sugar that must be

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added to the product to ensure viscosity and taste. It is established that the main raw material for the production of pectin in Ukraine is apple fruits. It is proven that pectin can be obtained from other fruits, berries, and vegetables, such as gooseberries, currants, cherries, pumpkins, etc. The intensification of the pectin production process should provide the population with a high-quality product that will prevent various types of intoxication by removing radionuclides from the body and contribute to the recovery of people in the post-war period. The practical significance of this study lies in the ability to help manufacturers find optimal sources of raw materials with a high pectin content to ensure the quality of the final product. In addition, this study will also facilitate the development of appropriate technological solutions for the optimal process of producing pectin from the selected raw materials

Keywords: food; shelf life; pectin pastes; vegetable raw materials; production process

Introduction

Pectin production is quite common in the world, especially in countries with developed food industries. Major pectin producers include the United States, the European Union (France, Italy, Germany, the Netherlands), India, China, and Brazil (Cho *et al.*, 2019).

Each of these countries has its pectin production methods, which are mainly based on traditional technologies. Each manufacturer can have its characteristics in the production process and the use of different types of raw materials. For example, in the United States, pectin is produced mainly from apples, citrus fruits, and sugar beets, as well as from juice and wine production waste (Cho *et al.*, 2019). In the European Union, the dominant sources of pectin are apples and citrus fruits, although other raw materials are also used. In China, pectin is produced mainly from citrus fruits and apples, while in Brazil it is produced from Brazilian guarana (Çilingir *et al.*, 2021).

Pectin production abroad usually takes place in large enterprises that have the appropriate technical and human resources to carry out all stages of the production process. Major pectin producers generally ensure the quality of the product and ensure that it meets the

requirements of international food safety standards (Güzel & Akpınar, 2019).

In Ukraine, pectin production is carried out on an industrial basis in several regions of the country, the most famous pectin plants are located in the Zakarpattia, Volyn, Khmelnytskyi, and Lviv oblasts. The most common source of pectin in Ukraine is apples, citrus processing products, and molasses formed during sugar production. However, in addition to traditional sources, Ukraine is exploring the possibility of obtaining pectin from other plants, such as sunflowers, peas, and corn, and from various food industry waste (Sukhenko *et al.*, 2019).

Nowadays, Ukrainian pectin plants produce pectin of various quality and applications – from food to medical and pharmaceutical industries. The plants export pectin to Europe and Asia and meet the domestic needs of the Ukrainian market (Guo *et al.*, 2020).

Pectins are polysaccharides that are commonly found in plant cell walls. They can be isolated from fruits, vegetables, berries, citrus fruits, and from some types of cereals.

Pectins are used in the food industry as a stabilizer, thickener, and binder. They provide structure and texture in foods such as jams,

jams, jellies, and other desserts. In addition, pectins also have health benefits, such as lowering blood cholesterol and supporting gastrointestinal health (Kazemi *et al.*, 2019).

Classical pectin production technologies usually include the following steps (Palamarchuk *et al.*, 2022):

- Collection and preparation of raw materials: the plant material is cleaned of impurities, cut, and mixed with water.
- Extraction: the prepared raw materials are exposed to acids or enzymes that help dissolve pectin and other components of the plant cell wall. Next, the resulting solution is filtered.
- Cleaning: the pectin solution goes through a series of cleaning processes that help remove impurities and other unwanted substances.
- Concentration: the resulting pectin solution is concentrated to reduce the volume and increase the pectin concentration.
- Drying: the concentrated pectin solution is dried, usually in hot air or the sun.
- Fractionation: pectin is divided into fractions with varying degrees of esterification and properties.
- Packaging: the finished product is packed in the appropriate container and prepared for transportation.

Depending on the type of raw material and production technology, the process may differ in detail, but the general principle remains the same.

The purpose of the study was to conduct a thorough analysis of the raw material base and various components of plant origin for the production of pectin and pectin-containing pastes.

Analysis of the main plant components for the production of pectins and pectin-containing pastes

The plant components used for pectin production may vary in composition and properties. The main sources of pectin are apples, citrus

fruits, sugar beets, and other crops (Acosta *et al.*, 2020). The study considers the composition and properties of these plant components.

Malic pectin has a high degree of methoxylation and the galacturonic acid content is about 70-75%. Apple pectin has a good gelling ability, which ensures its use as a stabilizer and thickener (Zheplinska *et al.*, 2021). Citrus pectin contains less galacturonic acid (40-60%) compared to apple pectin but has a high content of methoxyl groups, which makes it more soluble in water. Citrus pectin is used to increase viscosity and stabilize fruit juices (Mzoughi & Majdoub, 2021). Beetroot pectin contains the highest content of galacturonic acid (80-85%) compared to other sources of pectin. Beetroot pectin has a high gelling capacity, but less stability than apple or citrus pectin. It is used to thicken and stabilize liquid foods such as soups, sauces, and canned food (Zheplinska *et al.*, 2022).

Ukraine is a producer of sugar beet, which can be used as a source of raw materials for the production of pectin. Studies show that sugar beet contains approximately 10-15% pectin, which makes it a fairly effective source of raw materials for the production of pectin (Picot-Allain *et al.*, 2022). Raw materials for industrial production of pectin from the standpoint of economic feasibility of its use are mainly apple and citrus pomace, sugar beet pulp, citron melon, sunflower heart, and pumpkin (i.e., food processing waste). The content of pectin substances in plant materials varies widely: from 0.1-0.5% to 50%. The highest pectin content is found in lemon pomace (30-35%), orange and tangerine pomace (25-30%), sunflower pericarp (about 25%), beet pulp (20-25%), apple pomace (5-15%). Pectins are unevenly localized in different parts of plants. For example, in citrus fruits, the main amount of pectins is concentrated in the albedo, in apples – in the epider-

mis and adjacent tissues, in sugar beet – in the pulp (Picot-Allain *et al.*, 2022). Classification of pectin-containing raw materials by the content of pectin substances is given in Table 1.

Table 1. Characteristics of pectin substances by type of raw material

Type of pectin-containing raw materials		Pectin content, %
Subgroup	Raw material	
Group 1 “Vegetables”		
Tubers, root vegetables	Potatoes; beets, carrots	5.4...2.0 30.0...6.4
Leaf, stem	Cabbage, onions, celery	7.5...4.8 10.1...9.2
Fruited vegetables	Eggplant, pepper, tomatoes	11.0...9.2
Gourd	Pumpkins, melons, watermelons	23.6...1.7
Legumes, cereals	Green peas, corn, wheat, barley, oats, rice	2.5...1.5 3.0...4.0
Group 2 “Fruits and berries”		
Pome	Apples, pears, quinces, rowan	9.0...1.9
Stone fruits	Cherry, sweet cherry, plum, apricot	12.0...4.2 7.9...3.3 6.7...3.2
Subtropical citrus fruits	Figs, feijoas, persimmons, kiwis, grapefruits	14.0...4.9
Tropical citrus fruits	Pomegranates, bananas, lemons, oranges, tangerines	5.8...5.5
Group 3 “Other types”		
Leaves		14.0...4.9
Sunflower stalks		35.7...20.0
Sunflower hearts		24.0...12.0
Shells of cotton bolls		5.4...10.0
Tree bark	Pine, spruce, larch	9.0...8.0

Source: compiled by the author based on (Selvendran, 1985; Li *et al.*, 2022)

After analysing the data in Table 1, it can be concluded that the most promising raw materials for the synthesis of pectin and pectin-containing pastes in Ukraine may be different types of root vegetables, new melon varieties, seeds of different varieties, and sunflower (Bédouet *et al.*, 2003; Fishman *et al.*, 2019).

In scientific papers, researchers have proposed their classification of pectin-containing raw materials by the content of pectin substances, it has the following form:

➤ High-pectin raw materials (more than 35% pectin): Chinese yellow pea gum, concentrated lemon or lime juice, and apricot seeds.

➤ Medium-pectin raw materials (from 10% to 35% pectin): apple skins, orange zest, lemon zest, and pumpkin pulp.

➤ Low-pectin raw materials (less than 10% pectin): currant leaves, cherry stalks, black pepper, and hops.

Based on the results of the literature review, the level of development of the technological process and the analysis of the applicability of progressive solutions are established. There is a known method (Colodel *et al.*, 2020) for the production of purified pectin from fruit pomace by extracting ammonium oxalate with an aqueous solution of ammonium oxalate,

simultaneously grinding the raw material, followed by filtration and vacuum concentration of the extract. Pectins are precipitated from the extract with ethanol and dried. Then they are treated with an aqueous solution of ammonia. Hydrochloric acid is added to the reaction mixture and kept at 18°C for 1 hour, pectin is isolated. The complexing ability of pectin is 922.77 mg Pb²⁺/g.

The following method (Demir *et al.*, 2021) refers to the production of drugs that have a detoxification ability and can increase the purity and binding capacity of the resulting product. This method is used to extract pectin samples, such as beetroot, citrus, and apple pectin, with a 0.5% ammonium citrate solution. After filtration, an electrolyte is added to the pectin extract in the form of a 0.1 mol solution of potassium chloride and dialysis is performed through a cellophane membrane at a temperature of 38°C for 24 hours. The resulting dialysate is evaporated under a vacuum and treated with 96% ethanol. Pectins are separated and treated with a 5% ammonia solution in a ratio of 1:10 at pH 10.5 for 2 hours.

The method described in H. Chen *et al.* (2019) involve a mixture of beet pulp and apple pomace. This mixture swells in an acidic aqueous solution, then washed with water and subjected to hydrolysis with a mixture containing aqueous solutions of hydrochloric and acetic acids. The final stages of the process are the separation of hydrolysate, its cooling, and neutralization, precipitation of pectin with ethyl alcohol, its purification, and drying.

There are several ways to obtain food pectin from vegetable raw materials (Brito *et al.*, 2019; Bashta *et al.*, 2021). The essence of these methods is as follows: beet pulp and apple pomace are mixed in a ratio of 1:(1-9), cellulose phosphate is added in an amount of 2-4% (by wt.), the raw material is soaked in a

mixture of ultrafiltrate and water in a ratio of 1:(1-2) for 2 hours. Next, whey with an acidity of 290-300°T is heated to a temperature of 90-95°C, kept for 15-25 minutes, followed by cooling and filtration.

A special feature of the method of obtaining pectin, described by A. Bashta *et al.* (2021), is the hydrolysis of protopectin from fresh extracts of quince, apples, and pears with enzyme preparations of the cellulosic complex in the amount of 0.1-0.3% by weight of raw materials. To increase the yield of pectin, raw materials are frozen for 25-30 minutes at a temperature of 30-40°C, followed by defrosting with hot water. Hydrolysis is carried out at 45-50°C for 2-3 hours.

Preparation of pectin from apple pomace by the method (Naqash *et al.*, 2021) contains the following steps: washing of crushed apple pomace, acid thermal hydrolysis of washed raw materials, water extraction of pulp obtained after hydrolysis for more complete extraction of pectin, separation of the resulting hydrolysate and extract, precipitation and purification of pectin with ethyl alcohol, and drying. Before washing, the raw material is pre-evaporated for 15 minutes to intensify the separation of ballast substances, next the raw material itself is washed with water at a hydraulic module of 1:6 and a temperature of 50-60°C. Next, acid thermal hydrolysis of the washed raw materials with a solution of citric acid is performed at a temperature of 60-70°C. Pulp extraction is carried out with water at a temperature of 70-75°C, carried out by vacuum evaporation to the content of pectin substances of 10-12% to a completely dry mass.

The essence of the method of obtaining pectin from fruit pomace is that the raw material is washed with the addition of mineral acid in an amount that provides a pH of the solution of 2.5-3.0 for washing apple pomace, and 2.5-3.5 for citrus pomace (Hosseini *et al.*, 2020).

A well-known method for obtaining pectin from apple waste (Vásquez *et al.*, 2022), developed by Japanese scientists, involves processing raw materials with a solution of phosphoric acid, followed by filtration and purification on anion-exchange and cation-exchange resins.

The following method of pectin extraction uses the microwave radiation method (Dao *et al.*, 2021). Raw materials (oranges, tangerines, apples, and carrots) are pretreated with alcohol, and extraction takes place with an irradiation of 2.45 Mhz for several minutes and with repeated exposure. Solutions of hydrochloric, sulphuric acids, or solutions of ammonium oxalates are used as an extractant.

Japanese researchers (Ma *et al.*, 2020) developed a method for producing pectin under pressure for the food industry, for example, for making jam from pectin-containing plants, such as lemon, lime, and apple.

According to the method (Ázar *et al.*, 2020), pectins can be isolated from secondary products (mainly apple and citrus pomace) obtained by pressing juice from mature fruits and vegetables as a result of selective adsorption, and polyphenols – as a result of subsequent desorption of the adsorbent. The disadvantage of this method is the additional use of ethanol for the pretreatment of raw materials and the production of pectin with a low molecular weight

Depending on the application, different types of pectin-containing raw materials can be used for different purposes. For example, high-quality raw materials can be used to make jellies and marmalade, medium-quality raw materials can be used to make sauces and beverages, and low-quality raw materials can be used to make food additives and flavorings.

According to the results of analytical studies, it is established that the use of the above-mentioned plant raw materials is due to the high content of pectin and the latest trends

in its use in the food industry for the production of new products for health and preventive purposes, as well as large volumes of raw materials that are considered waste after the production of basic products at fruit and vegetable enterprises from the above-mentioned raw materials. Therefore, Ukrainian producers of pectin products and their derivatives can use traditional raw materials and apple pomace, melons, and sunflower.

Application of pectin substances in the food industry

In the context of the global environmental situation, which is associated with the growth of industrial production, the use of chemical technologies in the industry, agriculture, and everyday life, the development of nuclear energy, rational nutrition is of particular importance, which produces new opportunities for the use of pectins and their derivatives: in the production of canned food and confectionery, bakery products, soft drinks, and in the field of winemaking (Gamonpilas *et al.*, 2021; Gavahian *et al.*, 2021).

In the food industry, the main property of pectin is used – gelling ability. Pectin is widely used in the production of confectionery products of the pastille and marmalade group (marshmallows, jelly marmalade, etc.) and sweets (jelly and fruit jelly), which are in demand among the population. Unlike other gelling agents, pectin substances form jelly in aqueous solutions only in the presence of sugar and acid. The amount of sugar that is needed to form jelly varies depending on the amount and physicochemical properties of pectin. For thickening, not only the amount of acid added is important, but also its properties, which are conditioned by different concentrations of hydrogen ions. Solid jelly is produced in the presence of weak acids, such as tartaric, at a pH in the range of 3.0-3.2. The dry matter content

has a significant effect on the gelatinous properties. The higher the dry matter content, the higher the gelatinisation temperature and the strength of the final product. The content and composition should also be optimal.

C. Buathongja *et al.* (2020) found that an important technological aspect of the gelatinisation process is the dosage of buffer salt and acid. With the help of a buffer system, the pH value is regulated and thus affects the inversion of sugar during cooking (Freitas *et al.*, 2021). In the fruit canning industry, pectin is used in the production of jelly products: jellies, candies, and jams, and for the production of other products based on pectin for therapeutic and health-improving purposes (purees, jelly, juices, beverages, canned vegetables, etc.). To obtain the thickening and structural and mechanical properties of the resulting products, there is the type of pectin, the calcium content in fruits and water, pH, temperature, and filling time.

Traditional apple pectin, in addition to its pronounced sorption properties, has a high molecular weight and degree of esterification, an increased melting point, which enables accurate control of the temperature and time of gelatinisation. Fruit and jelly fillings based on apple pectin are ideal for bakery products and can withstand temperatures of about 220°C for 15-20 minutes, they are heat-resistant, do not boil off, and do not deform during baking. Traditional citrus pectin, unlike apple pectin, is mainly used in the production of dairy products (Biel-Nielsen *et al.*, 2022), for example, for the stabilisation of fermented milk drinks, cottage cheese, liquid yogurt, and in the production of fruit juices and beverages with pulp. The relatively low molecular weight and viscosity of citrus pectins, their neutral color, and taste allow them to be used for the industrial production of stabilized dairy products. When citrus pectin is added to fruit juices, the viscosity of the

product does not increase significantly, and the nutritional value increases.

The study by Wang *et al.* (2021) substantiates the use of traditional apple and citrus pectins in the production of various products. Various varieties of pectins with a high and medium degree of esterification were investigated: apple pectins with an esterification degree of 71.3% and 60.9%, and citrus pectins with an esterification degree of 70.0% and 60.1%, respectively. All samples were standardized in terms of gelling property according to a specially developed USA-SAG methodology. Apple and citrus pectins with the same standardization index have different properties in the resulting gels.

Wang *et al.* (2021) have shown that apple pectin gels have a higher strength, i.e., obtaining a product with the same fracture strength requires a lower consumption of apple pectin.

The study (Huang *et al.*, 2021) considered the influence of the properties of products with pectin on the change in the internal strength of the gel and it was found that at the pH of 2.9-3.1, characteristic of most confectionery products, the ultimate strength of the gel from apple pectin is significantly higher than from citrus pectin.

W.G. Sganzerla *et al.* (2020) investigated the effect of gel pH on gelling properties when standardizing apple and citrus pectins using the USA-SAG method. At pH 2.0-2.3 (according to the standard method), the standard or gelling property of apple pectin is higher.

To improve the quality of bakery products, both in Ukraine and abroad, various fillers are used that affect the components of wheat dough and ensure the production of high-quality products. Surfactants are increasingly used as fillers to intensify the bread production process, improve the quality of bakery products, and preserve their freshness (Marque *et al.*, 2020).

Currently, pectin and its derivatives are increasingly used in baking. In baking technology, such properties of pectin substances as swelling, viscosity, gelling property, regulating crystal formation, increasing water absorption, and emulsifying properties are important. The possibility of using various types of pectins in the preparation of bread – apple, citrus, beetroot – was investigated. It was found that the introduction of pectins into the dough affects the biological, colloidal, and microbiological processes of cooking. When pectin is added to the dough, its initial acidity increases and the pH decreases. The fermentation process in the dough is more active. Activation of the fermentation process is associated with the introduction of sugars together with pectin. When pectin is added to the dough, gluten is strengthened. Beetroot pectin, followed by apple and citrus pectin, has the most noticeable effect on strengthening the structural and mechanical properties of the dough. The introduction of pectin in bakery products not only improves the quality of finished products but also gives them medicinal properties. For the production of dietary wheat bread intended for binding and removing heavy metals from the body, it is advisable to use pectin products – fruit and vegetable powders, pectin extracts, and concentrates (Marque *et al.*, 2020).

Thus, the use of pectin and other pectin-containing products in baking can not only improve the quality of finished products but also expand the range of therapeutic and health-improving food products. A steady trend in the production of non-alcoholic beverages is an increase in the production of special-purpose beverages, which include beverages with the addition of biologically active components that have a health-improving effect on the human body. In the range of non-alcoholic products of therapeutic and health-improving action, more

and more importance is attached to drinks enriched with pectin substances (Staubmann *et al.*, 2023). The limited range of therapeutic and health-improving pectin-containing beverages currently produced is explained by the acute shortage of pectin in the food industry, which was already mentioned above. Expanding the production of soft drinks enriched with pectin substances can be solved by mastering the production of pectin extract. For example, apple pectin extract produced by industry contains at least 0.5% pectin substances, easily digestible sugars (glucose, fructose), proteins, organic acids, and a complex of macro- and microelements (Staubmann *et al.*, 2023).

Water-retaining, complexing, and emulsifying abilities of pectin substances determine their use in the production of dairy, meat, and fish products of mass assortment and therapeutic and health-improving purposes.

Pectin substances are used as a stabiliser in the production of yogurt, mayonnaise, margarine, and butter. Pectin substances are also used in the production of dairy products to stabilise and increase their biological value. The use of dairy raw materials (whole and skimmed milk, buttermilk, whey) in combination with pectin concentrates facilitates not only the rational use of all milk components but also allows obtaining biologically healthy pectin-containing dairy products with good organoleptic characteristics, which solves the problem of expanding the range of milk-based products (Çilingir *et al.*, 2021).

Effective blocking of the intake of radionuclides in the body has led to the use of pectins in the manufacturing of sausage products. The introduction of pectin into sausage products not only increases their biological value but also improves quality indicators.

No less effective was the use of pectins in the production of fish products, in particular

fish soufflé. It was found that the introduction of pectin at a concentration of 0.5–0.9% not only improves the quality indicators of fish soufflé but also increases its biological value, which allows recommending the developed product for therapeutic and health-improving nutrition (Bagal-Kestwal *et al.*, 2019).

Analysis of Ukrainian and foreign literature shows that at present, a versatile and very significant experimental material on pectin polysaccharides has been accumulated. However, despite the huge number of studies devoted to the isolation of pectin substances from various sources (Palamarchuk *et al.*, 2020), large-scale pectin production in Ukraine has not yet been implemented. This may be conditioned by many shortcomings of the developed technological schemes – the need for significant energy and capital expenditures, the high cost of acid-resistant equipment, and low profitability.

Thus, the search for new efficient, and cost-effective sources of raw materials for the production of pectin in Ukraine and the development of pectin technology is still an urgent task of the food and chemical industry.

The importance of pectin substances for human health

The human body is not able to use pectins as a source of carbon – they play a different role in it. Once in the human stomach, pectin swells and puts pressure on the walls, which produces a feeling of satiety. Thus, pectin is effective in the fight against excess weight. At the same time, pectin gel envelops the walls of the stomach, preventing acute exposure to many substances and the formation of ulcers (Albuquerque *et al.*, 2022). In addition, pectins easily form complexes with hydroxyl-retaining compounds – cholesterol, glucose, bile acids, fatty acids, and substances of phenolic nature, contributing to their elimination from the body, thereby

being an important preventive tool in the fight against hypercholesterolemia, hyperlipidemia, and diabetes mellitus. With a daily dose of 15 g of pectin for 2–3 weeks, bile excretion increases by more than 30%; cholesterol levels in the blood decrease by 13–15%. Modern researchers are also investigating the sorption properties of pectin substances from various sources (Wang *et al.*, 2019).

The paper (Souza *et al.*, 2020) presented the results of a series of experiments involving laboratory animals and discovered that a diet with the addition of amaranth and dietary fiber (pectin and cellulose) reduces cholesterol in the blood serum and liver. It was found that pectin can bind and remove lipids from the body, and in an amount 4 times higher than its weight (Li *et al.*, 2021). The specificity of this interaction is explained by the electrostatic nature of the generation of pectin complexes with low and very low-density lipoproteins (Chiu *et al.*, 2022). Due to the formation of gel-like structures, pectin can adsorb on its surface and remove from the body not only excess cholesterol but also other substances formed during vital activity (enzymes, products of bacterial origin, products of bile acid breakdown, etc.). One possible mechanism for lowering cholesterol in the blood when pectin is included in the diet is the binding of bile acids, which are products of cholesterol metabolism. This binding probably occurs due to the appearance of calcium bridges between the carboxyl groups of pectins and bile acid molecules (Bermúdez-Oria *et al.*, 2021).

Having a moisture-binding ability (in some cases up to 100 volumes per 1 volume of pectin) and at the same time sharply increasing in volume, pectin, along with other dietary fibers, improves the motor-evacuation function of the digestive canal and has a normalising effect on the intestinal microflora. Thus, pectins facilitate normal intestinal motility. The possibility of

using pectin for the treatment of hypertension was also investigated. It was found that with oral administration of pectin 0.5-1.0 g 3 times a day in patients with stage 1 and 2 of the hypertension disease, a persistent (for 4-10 months) decrease in blood pressure and improvement in general condition were observed. Pectin is particularly effective in combination with ascorbic acid (Kruger *et al.*, 2020). The affinity of pectin for phenols makes it an excellent dosage form when taking vitamins P: quercetin, rutin, robinin, and other flavonoids that are poorly soluble in water. Another phenolic compound, aspirin, in combination with pectin penetrates faster into the blood and irritates the stomach wall less (Mercado-Mercado *et al.*, 2020).

Skin ointments containing sulfur, salicylic and boric acids are prepared based on pectins (Hosseini *et al.*, 2020). Pectin acid in the intestine forms salts not only with metals but also with highly toxic nitrogenous bases generated during the decomposition of amino acids by the intestinal microflora (ammonia, putrescine, cadaverine, neuron, indole, skatole). Pectins from alkaloid plants (tobacco, rauwolfia) are produced in the form of salts with alkaloids. Tobacco nicotinate can be used to produce alternative smoking pills (Hosseini *et al.*, 2020)

Japanese researchers reported the formation of natural pectin salt with alkaloids (dimeric morphine) in the fruits of sleeping poppies (*Papaver somniferum*) (Wang *et al.*, 2022). Unlike the original pectin, such a salt, in which alkaloid molecules act as bridges that cross macromolecules of pectin, is resistant to the action of pectinolytic enzymes released by phytopathogenic fungi. This cross-linked pectin is a barrier to fungal infections entering the plant. Pectin acid also has a pronounced bactericidal activity, being an important regulator of the level of bacterial contamination of the intestine. Carbohydrate residues in pectin macromolecules

are homologous to bacterial cell ligands for intestinal epithelial receptors. The interaction of pectin and bacterial cells thus blocks the ability of the latter to adhere to the intestinal wall.

Pectin acid is the least toxic antibiotic for the human body, does not cause allergies, does not have the maximum permissible concentration, and does not cause dysbiosis – the normal intestinal microflora is insensitive to it. Moreover, good results were obtained in the study of kiwi pectins as probiotics (Shen *et al.*, 2019).

The hemostatic activity of pectins is known: being coagulants, they exhibit a hemostatic effect. In the presence of pectin, blood clots one and a half to two times faster (Wang *et al.*, 2021). The combination of hemostatic and bactericidal properties makes pectin an excellent wound-healing agent (Wang *et al.*, 2021). Pectins do not cause erythrocyte sedimentation, so a 0.75% aqueous solution of highly purified pectin is used as a substitute for blood plasma, which is more effective than saline.

Based on the results of the study (Brito *et al.*, 2019) it was found that pectin preparations have a pronounced hemostatic effect, which is characterised by a certain chemical composition: the degree of esterification, molecular weight, the content of acetyl groups, the pH of a 1% aqueous solution (Kazemi *et al.*, 2019).

An even more promising substitute for plasma is a preparation based on pectin acid ester (Cho *et al.*, 2019; Brito *et al.*, 2019). Pectin sulfate, on the other hand, inhibits blood clotting like natural poly heparin saccharide sulfate. Pectin sulfates also inhibit the activity of hyaluronidase enzymes in some diseases that destroy connective tissue in the body (Kazemi *et al.*, 2019; Kruger *et al.*, 2020). Pectin sulfate esters are also applicable as anti-inflammatory agents.

American oncologists have proven that pectin forms a strong complex with cancer cells

(Chauhan *et al.*, 2020). It is assumed that galactose sequences on pectin macromolecules are specific to protein complexes on the surface of cancer cells responsible for adhesion to healthy tissues. Rhamnogalacturonan I has the greatest antimetastatic effect (Chauhan *et al.*, 2020). The ability to inhibit the proliferation of malignant cells was found in citrus pectin (Prado *et al.*, 2019).

Pectins dramatically activate the immune response (Su *et al.*, 2023). Pectins from angelica, Eleutherococcus, hollyhock, astragalus, marigold, mullein, plantain, stinging nettle, and many other plants stimulate supplements and promote the production of interleukin-2. The antiviral effect of tragacanth gum from Astragalus can be explained by this. This gum at a dose of 3.2-100 mcg/kg of body weight completely protects mice from infection with cytomegalovirus (Frediansyah, 2021). More recently, pectin has been isolated from the leaves of *Aspalathus linearis*, which inhibits the reproduction of HIV, again affecting the human immune system (Webster *et al.*, 2019).

At the Nutrition Research Institute (Washington), studies were conducted on screening pectin drugs for the relief of toxic pulmonary oedema with nitrogen dioxide. The most effective product purified by diafiltration is obtained from beet pectin (Teaford *et al.*, 2020).

The Centre for Preventive and curative nutrition (Prague) developed a method for treating obesity using diet therapy in combination with a protein-pectin complex (Yang *et al.*, 2021). Pectin derived from hollyhock is a fairly strong antitussive agent (Ciriminna *et al.*, 2020).

The most important factors for obtaining high-quality pectin are the purity of raw materials and their chemical composition. To ensure the quality of pectin, it is necessary to use high-quality raw materials and control production processes, this area of research will be presented in the following publications.

The papers of many Ukrainian and foreign researchers are devoted to the investigation of methods for obtaining pectin from a variety of pectin-containing plant raw materials. The papers mainly cover studies on the extraction of pectin from various plant raw materials using reagents of various origins (Sukhenko *et al.*, 2019), but too little attention is paid to the analysis of the raw material base for its production.

Some Ukrainian and foreign enterprises receive juice from pumpkin pulp, which is used in the food industry. This leads to a significant amount of waste in the form of pumpkin pomace, which contains a variety of biologically active substances such as vitamins, carbohydrates, polysaccharides, and fatty acids, which can be a promising source for their production. However, today enterprises dispose of pumpkin waste (pomace from the pulp is thrown away, and meal from seeds is sometimes used for feeding livestock) (Palamarchuk *et al.*, 2022). It is known from literature sources that the mass fraction of pectin substances in pumpkins range from 10% to 20%. Therefore, the technology of obtaining pumpkin pectin, as well as grape pectin, needs further study and improvement.

Extracting pectin in its pure form from plant raw materials is impractical and very difficult, especially in certain cases. In the process of such extraction, all multivitamins that are inherent in this raw material are lost (Su *et al.*, 2023). Therefore, to completely and efficiently remove pectins from plant raw materials, it is necessary to solve many problems. One of the important tasks is to maintain the optimal temperature during the process since pectin belongs to macromolecular compounds and does not melt. However, when the temperature reaches more than 90°C, it begins to decompose, its molecular weight decreases, and its ability to bind toxic substances and heavy metals is lost (Shen *et al.*, 2019). Therefore,

it should be highlighted that pectin can not be boiled. This is especially important when choosing equipment for the hydrolysis of plant raw materials.

Another important task in the production of pectin pastes is the mechanical purification of pectin extract from solid microparticles since the presence of foreign impurities can affect the quality of the finished product – its color and taste. For this purpose, filtration or centrifugal cleaning is most often used.

In addition, pectin-containing raw materials should not contain sugars that can be reduced, as this can lead to the formation of dark compounds, such as melanoidin, which complicate the process of lightening pectin extract. Therefore, the residual sugar content during the production of pectin pastes should be minimal, as this is an important requirement for obtaining light products. The main properties of pectin-containing substances that must be considered in the production of pectin-containing pastes are as follows: solubility, viscosity, gelling power, and complexing ability. Equally important factors are the establishment of optimal operating modes of production processes: the ratio of dry substances to the liquid phase, pH of the medium, temperature, and time. These conditions may be different for different raw materials and their physical and chemical state.

Based on the realities of today, pectins have gained special importance in the last three decades, when information appeared about the ability of pectin to form complexes and remove lead, copper, mercury, zinc, cobalt, molybdenum, radionuclides cesium-137, strontium-90, radium, etc. from the human body. Pectin substances also can absorb and remove biogenic toxins, analytics, xenobiotics, pesticides, metabolic products, and biologically harmful substances that can accumulate in the human

body. Pectin substances can also have a positive effect on the content of cholesterol, bile acids, urea, mast cell products, and toxin-forming fungi. Researchers around the world are studying the properties of pectin, discovering more and more of its healing qualities.

Because pectin is based on galacturonic acid molecules, it is a unique biologically active product with health-improving and radioprotective properties (Albuquerque *et al.*, 2022). Pectin substances are used to treat diabetes mellitus, atherosclerosis, and hemophilia, in the healing of wounds and burns, and in the treatment of bacterial infectious diseases of the gastrointestinal tract. As a component of plants, pectin substances have always been components of food since the origin of man. According to the World Health Organisation, pectin substances are recognised as absolutely toxicologically safe food products. There are no restrictions on their use and they are recognised in most countries of the world as valuable food products (Sukhenko *et al.*, 2019).

Pectins are currently one of the most demanded and widely used food ingredients due to their multifunctionality in the world of pectin, also known by the code name E-440 (Chiu *et al.*, 2022). On the one hand, dietary fibers are used as technological additives that can change the structure and chemical properties of food, and on the other hand, dietary fibers are excellent functional ingredients that can favorably affect individual systems and the entire human body.

Conclusions

In the current environmental situation, especially in Ukraine, there is an urgent need for healthcare products, among which pectins occupy a special place. Evaluating modern achievements in the study of pectin production, it can be stated that pectins are a unique

product that has gained a strong place in modern food technologies. At the same time, it has a wide range of biological activities.

Pectins are used for therapeutic and preventive purposes – in the treatment of diabetes, atherosclerosis, heart ischemia, and diseases of the gastrointestinal tract, they increase the body's resistance to allergies, normalise the amount of cholesterol, and are used as regulators of metabolic processes in the human body. In the literature, there are data on the effectiveness of pectins in the treatment of cancer tumors. Thus, modern research allows expanding the scope of application of pectin substances, which leads to an increase in market demand for pectin.

Based on the results of the study, the main physicochemical, structural, and biological properties of raw materials of plant origin for the synthesis of pectins isolated from various types of traditional and unconventional raw materials are analysed. The possibilities of using pectins in the food industry for lightening whey, improving the quality of bread, and making functional products that have a therapeutic and health-improving effect are revealed.

It is established that at the present stage of development of industrial production, manufacturers are faced with the task of developing and applying new technologies for the production of pectin and pectin pastes with high biological value, which will provide for minimal

impact on their natural properties and will not disrupt the balance of the main components. The use of pectin will increase immunity and avoid many diseases in the human body, and the development and introduction of new varieties of pectins in industrial production will expand the range of useful and inexpensive food products with unique properties.

The combination of different types of pectins from raw materials of plant origin can contribute to the creation of completely new products or dosage forms with improved properties, open up new markets for export, and create new jobs in the post-war period. Possible areas for further research in the context of this problem may be the following: the investigation of the influence of plant growth factors and processing on the content and quality of pectin, the use of new methods of analysis and quality control of pectin, the study of the use of industrial waste for obtaining additional products, the improvement of purification and refining of pectin, the study of the possibilities of using genetically modified organisms for the production of pectin, or the use of enzymatic processes to increase the yield of pectin.

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Conflict of Interest

None.

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Аналіз сировинної бази для виробництва пектину

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Анотація. Додавання пектину в харчові продукти має важливе значення оскільки цей природний полісахарид відіграє важливу роль у покращенні якості та стійкості продукту, він дозволяє якісно зберігати продукти, які мають тривалий термін зберігання, що важливо для збереження здоров'я та добробуту споживачів. Метою дослідження є вивчення основних сировинних джерел рослинного походження для синтезу пектину, які можуть бути використані в якості перспективної сировини для підприємств харчової промисловості України. Дослідження проводили з використанням різноманітних методів аналізу, проведено ґрунтовний порівняльний аналіз наукових праць вітчизняних та закордонних вчених, які розміщено в наукометричних базах Scopus, Web of Science, Journal Citation Reports, Scimago Journal & Country Rank та Google Scholar. За результатами аналітичних досліджень, було проведено аналіз основних сировинних джерел, які використовуються для виробництва пектину та пектиновмістних паст, встановлено основні проблеми технологічного процесу виробництва. Встановлено, що додавання пектину в харчові продукти може мати значну кількість, переваг: збільшення в'язкості продукту, що корисно для створення густої текстури продукту; підвищення стійкості продукту до термічної обробки, зменшуючи ризик розділення продукту або зниження якості; збільшення функціональності, введення в продукти може

допомогти покращити консистенцію та вигляд продукту, додати смак та кольорові властивості та знизити кількість цукру, який потрібно додавати до продукту для забезпечення в'язкості та смаку. Встановлено, що основною сировиною для виробництва пектину в Україні є плоди яблук. Доведено, що пектин можна отримати з інших фруктів, ягід та овочів, таких агрус, смородина, вишня, гарбузи та інші. Інтенсифікація процесу виробництва пектину повинна забезпечити населення якісним продуктом, що дозволить запобігати різного типу інтоксикаціям, шляхом виведення з організму радіонуклідів і сприятиме оздоровленню людей у післявоєнний час. Практичне значення цього дослідження полягає в можливості допомогти виробникам знайти оптимальні джерела сировини, які мають високий вміст пектину, з метою забезпечення якості кінцевого продукту. Крім того, це дослідження також дозволить розробити відповідні технологічні рішення для оптимального процесу виробництва пектину з вибраної сировини

Ключові слова: продукти харчування; термін зберігання; пектинові пасти; рослинна сировина; процес виробництва



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Protective properties of the fleece of Taurian ewes of the Askanian fine fleece breed depending on the breeding differentiation rank

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Abstract. The study of factors affecting the humidity and contamination of the outer and inner zones of the staple, which further affects the yield of pure wool and its technological properties, is one of the current problems of fine-fleeced sheep breeding. Purpose of the study – evaluate the protective properties of wool fleece depending on the rank of breeding differentiation of sheep. The determination of ranks is based on the regularities of the normal distribution of animals in the population and herd reproduction indicators. 10 ranks were used. The paper presents the results of a laboratory study of the content of mineral impurities and the degree of contamination of the staple. Sheep were divided into 10 ranks of breeding differentiation. The regularities of the normal distribution of animals in the population are considered. The obtained data indicate that the variety of sheep in terms of the content of mineral impurities in wool is very large. The

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coefficient of variation is 35% with a variation in the ranks of breeding differentiation from 13.7 to 38.4%. With an increase in the group of the total value of sheep for breeding purposes, the value of the coefficient of variation decreases ($r_s = -0.871 \pm 0.245$). With an increase in the ranks of breeding differentiation, the average absolute indicators of contamination of the outer zone of the staple tend to increase ($r_s = +0.257 \pm 0.483$), and the relative values decrease ($r_s = -0.600 \pm 0.400$). The average absolute contamination rate of the inner zone of the staple is 3.02 cm with a range of ranks from 2.83 to 3.29 cm. According to the relative degree of contamination, these indicators are 32.5% and from 31.0 to 35.2%, respectively. With an increase in the breeding differentiation rank of sheep, the absolute indicators of contamination of the length of the inner zone of the staple increase ($r_s = +0.600 \pm 0.400$), and relative values tend to decrease ($r_s = -0.486 \pm 0.437$). The individual variety of ewes in terms of the degree of contamination of the inner zone of the staple is quite high. The coefficients of variation for absolute and relative indicators of this feature are 28.5 and 30.4%, respectively. The value of the coefficients of variation decreases slightly with an increase in the ranks of breeding purposes of animals. The rank correlation is -0.371 ± 0.464 in absolute terms and -0.543 ± 0.420 in relative terms. Breeding differentials of the leading groups of ewes are low. Using this rank technique allows controlling the system of sheep valuation, supplementing it with the value of breeding differentials at the final stages of analysis and selection; in production conditions allows forming technological groups of sheep to produce outstanding ram breeders

Keywords: merinos; sheep; impurity content; degree of contamination; staple; pure wool

Introduction

Wool is the main product of fine-fleeced sheep and an important raw material for the light industry. However, its production in many countries and around the world has recently declined significantly (Avercheva, 2020; Suprun *et al.*, 2021). One of the reasons for this is that the cost of wool production is higher than the selling price. Increasing the level of profitability of sheep farming largely depends on the quality of products. A significant reserve for the production of high-quality wool is the breed improvement of sheep. This is evidenced by the positive effect of using Australian Merino and New Zealand Corriedales. As noted by N. Boyko *et al.* (2022) the assessment of the physical and technical parameters of wool is necessarily regulated by the current state standards and instructions for conducting breeding work. This

determines the effectiveness of breeding for further improvement of sheep breeds.

Current positive trends in the development of the agricultural sector of Ukraine also indicate encouraging prospects for sheep farming. The issue of creating specialised genotypes of mutton and dairy sheep is being resolved (Vdovychenko & Zharuk, 2019). Existing breeds are being improved to increase precocity and growth intensity (Makovicky *et al.*, 2019; Pomitun *et al.*, 2021), fattening and mutton qualities (Mashner & Lyutskanov, 2019). A comprehensive assessment of sheep with productivity is carried out aimed at improving the quality of wool (Korkh *et al.*, 2022; Ramos *et al.*, 2023). The protective properties of wool suint are studied in sheep of various breeds (Stapai *et al.*, 2019; Korbych & Salyvonchik, 2019; Korbych & Odnorih, 2021).

Recently, when crossing sheep of the wool direction of productivity with sheep of mutton breeds, offspring of an improved meat type are obtained, which increases the profitability of both wool and lamb production. N. Boyko *et al.* (2022) investigated the qualitative characteristics of sheep wool of the Prydniprovskya mutton breed in relation to their gender and genotype. Thus, in sheep and yearling ewes, the degree of wool fineness is mainly 58–60 points of quality, in replacement rams and breeding rams – 56–60 points. The light colour of the suint was observed in yearling ewes of the MOI genotype, which outperformed the ML, MDt, and MT genotypes by 60%, 20%, and 50%, respectively. The average score for suint quality ranged from 3 points in yearling ewes of the MDt genotype to 5 points in sheep of the MOI genotype. The share of technologically more valuable light suint in the wool of MOI yearling ewes led to an increase in the overall score for its quality by 2.0 points or 66.7 %. According to P. Stapai *et al.* (2019) the use of Suffolk rams on Prekos ewes also had a positive effect on the quantitative and qualitative parameters of suint in their offspring.

According to M.L. Heimbuch *et al.* (2023) the genetically determined makings of high sheep productivity based on traits that meet the needs of global and domestic markets for sheep products are of particular importance. The hereditary makings of organisms change under the influence of selection (Herman *et al.*, 2019; Ramos *et al.*, 2021). The use of modern breeding methods is an important scientific and industrial task. The theoretical basis for the selection of farm animals, including sheep, consists of patterns of heredity, variability, selection, breeding, and features of the development and use of the breeding structure of the population. The effectiveness of the breeding process depends on the actual effectiveness of the selection and use of breeding rams and

ewes (Pomitun *et al.*, 2020; Ramos *et al.*, 2023). Sheep make up the largest group of animals in the herd structure. They are in the production process for a long time and significantly affect the formation of a variety of hereditary productivity traits of new generations of descendants in the population. The individual productivity variety of sheep is significantly higher than that of sheep producers. But it is very difficult to effectively use this variety for breeding purposes, since the total number of ewes in the herd is too large for the rapid detection and widespread use of individual highly productive ewes. Therefore, there was an objective need for breeding division of the number of ewes into separate groups (ranks of breeding differentiation), depending on the complex level of animal productivity. In this regard, the purpose of the study was to evaluate the protective properties of the sheep wool fleece depending on the rank of breeding differentiation.

Materials and Methods

The study was conducted on a number of Taurian ewes ($n = 130$) of the Askanian fine-fleeced sheep breed, according to breeding records from the “Chervonyi Chaban” breeding plant in the Kherson oblast.

During valuation, the entire number of sheep (4 flocks) was divided according to the breeding differentiation ranks. The determination of ranks is based on the regularities of the normal distribution of animals in the population and herd reproduction indicators. 10 ranks were used. The 1st rank (elite unique) includes sheep with an excess of the average level of productivity by three standard deviations ($+3\sigma$) or more; the 2nd (elite selective) – excess from $+2$ to $+3\sigma$; 3rd (elite breeding) – from $+1$ up to $+2\sigma$; 4th (repair elite) – within $+1\sigma$; 5th (standard elite) – animals that have average productivity indicators; 6th (mediocre elite) – deviation within up

to -1σ from the average level of productivity; 7th (first-class standard) – from -1 to -2σ ; 8th (first-class mediocre) – deviation to -3σ ; 9th (second-class) and 10th (rejects) – deviation from the average level of productivity exceeds -3σ .

For laboratory testing of wool within each flock of sheep, 5% of animals were selected by random sampling (every 20th ewe). Wool samples weighing 30–40 g were selected from each animal selected for analysis, which were subjected to laboratory tests. The content of mineral impurities and the depth of contamination of the outer and inner zones of the staple were determined in wool. The content of mineral impurities in the wool was determined by washing in a soap-soda solution, followed by drying to a constant weight of samples. Contamination of the outer and inner zones of the staple was determined by measuring the depth of penetration of mineral impurities. Measurements were made directly in the staples and between staples.

Within the groups formed by the rank of breeding differentiation and for the entire population of experimental ewes, the average development indicators of each of the considered traits ($M \pm m$) and variability coefficients (Cv , %), which were calculated by the ratio of the mean square deviation to the average in the group; breeding differentials (Sd) and the value of rank correlation (rs) as an indicator of the dynamics of genetic and population parameters were determined. During the study, the technology of keeping sheep in the “Chervonyi Chaban” breeding plant did not change. Ewes received a diet according to generally accepted feeding standards. When working with animals, the bioethical requirements of the Law

of Ukraine No. 3447-IV “On the Protection of Animals from Cruelty” (2006) and ARRIVE guidelines for reporting experiments using live animals were observed.

Results and Discussion

As noted by R. Atav *et al.* (2020), the complex productivity of fine-fleeced sheep includes a significant number of qualitative characteristics. In breeding practice, qualitative characteristics in most cases are evaluated during sheep valuation (main, preliminary, and additional). They are also evaluated in production conditions when classifying wool and preparing raw materials for sale. A significant number of qualitative features are evaluated by laboratory methods. Conducting studies of wool in certified laboratories allows evaluating its characteristics and determining a number of features that determine the shearing of wool and its changes in the sheep ontogenesis. These signs include: the content of fat and sweat in wool; the sweat: fat ratio; the content of impurities and moisture in the fleece; absolute and relative contamination of the outer and inner zones of the staple. These signs characterise the protective properties of wool fleece as one of the important components of its quality properties.

In the course of the study, the protective properties of the wool fleece (for each rank) are established based on the content of mineral impurities in the wool and the degree of contamination of the length of the inner and outer zones of the staple. On average, the constant weight of unwashed wool contains 17.1%. Percentage of mineral impurities with fluctuations in sheep groups from 16.1 to 19.9% (Table 1).

Table 1. Content of mineral impurities in a constant weight of unwashed wool, %

Rank number	n	M±m	Cv, %	Lim	
				min	max
1-2	3	19.6±1.56	13.7	16.7	22.0

Table 1. Continued

Rank number	n	M±m	Cv, %	Lim	
				min	max
3	12	19.9±1.72	30.0	11.1	26.4
4	26	17.7±1.13	32.7	9.0	30.6
5-6	52	16.1±0.85	38.4	7.4	31.6
7-8	28	17.2±1.12	34.3	5.8	29.5
9-10	9	17.0±2.17	38.4	10.6	31.7
In the entire sample	130	17.1±0.53	35.0	5.8	31.7

With an increase in the rank of breeding differentiation of sheep, the slightly increasing content of impurities in wool increased slightly ($r_s = +0.771 \pm 0.358$). This situation can occur when combining clippings of pure wool and sufficient size from animals with a relatively low density and suint content in fleece. In this regard, it is possible to modify the patterns due to economic and environmental conditions in the industrial use of sheep. The limits of individual indicators of the content of mineral impurities in wool ranged from 5.8 to 31.7%. The difference was 25.9%. According to the gradations of breeding differentiation, this difference ranged from 5.3 to 24.6%. For breeding groups of sheep, the minimum mineral impurity content increased ($r_s = +0.657 \pm 0.377$), the maximum – decreased ($r_s = -0.829 \pm 0.280$), and the difference between them also decreased ($r_s = -0.800 \pm 0.300$).

The variety of ewes in terms of the content of mineral impurities in wool is very large. The variation coefficient is 35% with a divergence

in the ranks of breeding differentiation from 13.7 to 38.4%. With an increase in the group of total value of sheep for breeding purposes, the value of the variation coefficient decreased ($r_s = -0.871 \pm 0.245$). But this is not an obstacle to improving the protective properties of fleece, since there was a significant variety of sheep in terms of the content of mineral impurities in the coat. Average differential of the first three groups of sheep by this feature varied from 0.6 to 2.8% (relative – from 3.5 to 14.6%). For the first three groups of sheep, the absolute breeding differential was 1.9%, and the relative differential was 11.2%. This situation with indicators of the content of mineral impurities in the fleece and a system of careful selection of sheep according to the complex level of productivity can be explained by relatively lower indicators of fat content in sheep wool, some loss of fleece density, and insufficiently high resistance and structure of suint content to atmospheric factors and production conditions of keeping sheep during the year.

Table 2. Depth of penetration of the outer contaminated zone of the sheep staple, cm

Rank number	n	M±m	Cv, %	Lim	
				min	max
1-2	3	5.17±0.44	14.8	4.5	6.0
3	12	4.46±0.27	21.9	2.5	6.0
4	26	5.00±0.16	16.2	4.0	6.5
5-6	52	4.72±0.11	17.5	3.0	7.0
7-8	28	4.96±0.18	19.0	3.5	7.0
9-10	9	4.78±0.26	16.6	4.0	6.5
In the entire sample	130	4.82±0.08	17.8	2.5	7.0

The average absolute depth of penetration of the contaminated outer staple zone for the entire sheep population is 4.82 cm with a variation in the ranks of breeding differentiation from 4.46 to 5.17 cm (Table 2).

According to relative characteristics, these indicators are 52.5% and from 48.2 to 58.6%, respectively (Table 3).

With an increase in the ranks of breeding differentiation, the average absolute indicators of contamination of the outer zone of the staple tended to increase ($r_s = +0.257 \pm 0.483$), and the relative values decreased ($r_s = -0.600 \pm 0.400$). The limits of individual values of absolute contamination indicators of the outer zone of the staple were in the range from 2.5 to 7 cm, and relative values – from 33.3 to 77.7%. For breed-

ing groups of sheep, the difference in individual extreme values of absolute indicators of contamination of the outer zone of the staple ranged from 1.5 to 4.0 cm, and relative – from 15.1 to 37.3%. In the best sheep in terms of complex value, the absolute minimum indicators of individual diversity remained almost unchanged ($r_s = +0.129 \pm 0.496$), the maximum slightly decreased ($r_s = -0.643 \pm 0.383$), and the difference between them tended to decrease ($r_s = -0.286 \pm 0.479$). According to relative characteristics, the minimum values of individual animal variety for this trait did not change ($r_s = -0.043 \pm 0.499$), the maximum significantly decreased ($r_s = -0.814 \pm 0.290$), the difference between them also significantly decreased ($r_s = -0.814 \pm 0.290$).

Table 3. Proportion of contamination of the outer zone of the sheep staple, %

Rank number	n	M±m	Cv, %	Lim	
				min	max
1-2	3	54.8±4.36	13.8	47.4	62.5
3	12	48.2±2.59	18.6	33.3	70.6
4	26	51.9±1.14	11.2	44.1	66.7
5-6	52	51.4±1.05	14.8	36.8	71.4
7-8	28	55.0±1.67	16.1	44.4	77.8
9-10	9	58.6±2.64	13.5	44.4	71.4
In the entire sample	130	52.5±0.70	15.2	33.3	77.8

On the studied livestock, a significant variety of ewes was found in terms of the degree of contamination of the outer zone of the staple in absolute and relative terms. The coefficients of variation were 17.8% and 15.2%, respectively, with fluctuations in the breeding groups of animals from 14.8 to 21.9% and from 11.2 to 18.6%, respectively. The value of the variation coefficients practically did not change due to the selection of sheep for the complex level of productivity – the rank correlation for absolute and relative characteristics was -0.251 ± 0.483 and $+0.143 \pm 0.495$, respectively.

Breeding differentials for absolute and relative indicators of contamination of the outer zone of the staple of sheep of the first leading ranks ranged from -0.36 to $+0.35$ cm and from -0.6 to -4.3% , respectively. Practically, the belonging of sheep to the best groups for breeding purposes was slightly determined by the specifics of contamination of the outer zone of the staple. Although in general, with an increase in the rank of breeding differentiation of sheep, the relative degree of contamination of the outer zone of the staple decreased ($r_s = -0.600 \pm 0.400$).

Table 4. Penetration depth of the inner contaminated zone of the sheep staple, CM

Rank number	n	M±m	Cv, %	Lim	
				min	max
1-2	3	3.17±0.17	9.1	3.0	3.5
3	12	2.96±0.16	18.3	2.0	4.0
4	26	3.29±0.16	24.4	1.5	5.5
5-6	52	2.90±0.13	33.1	1.0	5.5
7-8	28	3.07±0.18	9.4	1.5	6.0
9-10	9	2.83±0.19	19.7	2.0	3.5
In the entire sample	130	3.02±0.08	28.5	1.5	6.0

The average absolute contamination rate of the inner zone of the staple is 3.02 cm with a range of ranks from 2.83 to 3.29 cm (Table 4).

According to the relative degree of contamination, these indicators are 32.5% and from 31.0 to 35.2%, respectively (Table 5).

Table 5. Proportion of contamination of the inner zone of the sheep staple, %

Rank number	n	M±m	Cv, %	Lim	
				min	max
1-2	3	33.9±3.29	16.8	27.3	37.5
3	12	32.3±1.48	15.9	23.8	38.9
4	26	32.3±1.66	26.2	15.8	50.0
5-6	52	31.0±1.52	35.3	10.5	57.1
7-8	28	34.6±2.14	32.8	17.7	66.7
9-10	9	35.2±2.89	24.6	22.2	46.2
In the entire sample	130	32.5±0.87	30.4	10.5	66.7

With an increase in the rank of breeding differentiation of sheep, the absolute indicators of contamination of the inner zone of the staple increased ($r_s = +0.600 \pm 0.400$), and the relative values tended to decrease ($r_s = -0.486 \pm 0.437$). The limits of individual absolute indicators of contamination of the internal staple were in the range from 1.5 to 6.0 cm, and relative characteristics – in the range from 10.5 to 66.7%. According to the ranks of sheep breeding differentiation, the minimum absolute and relative indicators of individual animal variety tended to increase. The rank correlation value was -0.486 ± 0.437 and $+0.457 \pm 0.445$. For the maximum individual indicators, there was a downward trend –

the rank correlation was -0.657 ± 0.377 and -0.229 ± 0.487 , respectively. The difference between the maximum and minimum individual indicators of contamination of the inner zone of the sheep staple also slightly decreased with an increase in the rank of breeding differentiation of animals. The rank correlation was -0.657 ± 0.377 and -0.388 ± 0.461 , respectively.

The individual variety of ewes in terms of the degree of contamination of the inner zone of the staple is quite high. The coefficients of variation for absolute and relative indicators of this trait were 28.5% and 30.4%, respectively. The value of the coefficients of variation slightly decreased with an increase in the ranks of breeding purposes of animals. The

rank correlation was -0.371 ± 0.464 in absolute terms and -0.543 ± 0.420 in relative terms. Breeding differentials of the leading groups of ewes are low.

The established regularities indicate that the overall rank value of sheep is determined by other qualitative and quantitative indicators of the wool productivity of animals. The lack of protective properties of the fleece characterises the sheep population as a whole. Therefore, it is necessary to select and make extensive use of outstanding animals in this regard. Breeding traits that determine the consumer and economic value of sheep products are included in the system of conscious genetic improvement through breeding work in the population. Shearing pure wool is the main indicator of sheep's wool productivity. Many researchers emphasise that an insufficient amount of fat in the fleece of sheep leads to a significant deterioration in the natural properties of wool. According to N.M. Korbych & O.M. Salyvonchik (2019), N.M. Korbych & S.Iu. Odnorih (2021), the amount of suint, impurities, and moisture in the fleece affects both the amount of shearing of unwashed wool and the qualitative features of the sheep's coat.

P. Stapai *et al.* (2019) report that reliable protection of the natural properties of wool during its growth, and during primary processing and subsequent use is provided precisely by suint. Thus, a study of quantitative and qualitative indicators of wool suint content was conducted on full-aged sheep of the Askanian fine-fleeced, Prekos, and Ukrainian mountain Carpathian (UMCB) breeds. It was found that the suint of sheep of the Askanian fine-fleeced breed contains 18.4% grease, in the Prekos – 12.9%, and in the UMCB – 8.2%. However, in the suint of UMCB sheep, the proportion of sweat is the highest – 20.6%, in fine-fleeced sheep, its amount is much lower: 15.5% in the Askanian

breed and 12.8% in the Prekos. Individual variations in wool suint are quite significant, which affects the production of high-quality wool (Korbych & Odnorih, 2021).

An important criterion for evaluating the protective properties of sheep suint is the ratio of sweat to wax in its composition. The best protective properties are provided by suint, in which there is less than one unit of sweat per unit of wax. P. Stapai *et al.* (2019) found that in sheep of the Askanian fine-fleeced breed, the wax:sweat ratio is 1:0.84, and in animals of the Prekos and UMCB breeds, respectively: 1:0.99 and 1:2.52. Similar differences were found in relation to the pH of sweat. Thus, the lowest pH values of sweat were found in sheep of the Askanian fine-fleeced breed – 7.8, slightly higher alkalinity of sweat was observed in sheep of the Prekos breed – 8.7, and the highest (9.6) – in the UMCB. By reducing the content of unesterified fatty acids and polar lipids, and increasing the content of unesterified cholesterol and lanosterol, the protective properties of wool wax are improved. The results obtained by I. Korkh *et al.* (2022) suggest that long-term exposure to high air temperature on the body of sheep before shearing can lead to a deterioration of such an important indicator as the yield of washed wool. According to the data, the ratio of parts of wool fat to sweat in unwashed wool turned out to be low and was almost at the same level (desirable for fine-fleeced sheep): one part of fat accounted for from 0.7 to 0.8 parts of sweat.

Now considerable attention of breeders is paid to improving the meat qualities of sheep (Thorne *et al.*, 2021; Suliman *et al.*, 2021). However, wool remains a universal product that enjoys steady consumer demand on the global market (Tsybukh *et al.*, 2021). Researchers and practitioners continue to work on creating new, more competitive breeds and types of

sheep (Masters & Ferguson, 2019). According to N. Boyko *et al.* (2022), the vision of important aspects of the development of qualitative characteristics of wool, including in sheep meat productivity, will contribute to the organisation of measures to manage the processes of using raw materials at the stage of primary processing and improve the technological processes of its processing. The researchers note that the physical and technical characteristics of wool depend on the strategy of managing the breeding process. Failure to consider these parameters with an objective assessment of them can lead to depreciation of fleece, and, ultimately, to a decrease in the level of profitability of wool production.

Therefore, the laboratory studies of wool on the protective properties of Merino fleece allow the authors to objectively evaluate the features and components that form wool shearing in sheep ontogenesis, evaluate the qualitative characteristics of sheep wool cover, and detail the system of animal assessment during valuation. The ultimate goal of breeding is to improve the average level of productivity and adaptation indicators. That is why the use of this rank technique allows controlling the animal assessment system directly in the process of sheep valuation, supplementing it with the value of breeding differentials at the final stages of analysis and selection.

Conclusions

The proportion of ewes of different breeding ranks is as follows: unique and selective elite – 2.3%, breeding elite – 9.3%, repair elite – 20%, standard and mediocre elite – 40%, first-class standard and mediocre – 21.5%, second-class and rejects – 6.9%. Unique and selective ewes form the basis of the breeding stock to produce outstanding productive breeding rams. The first 4 ranks (31.6%) provide the main number

of repair young stock to replenish the breeding stock of ewes in the herd.

The average indicators for the studied characteristics of the sheep population are: the content of impurities in wool – 17.1%, the degree of depth of contamination, in particular, the outer zone of the staple – 52.5%, the inner zone of the staple – 32.5%. When selecting sheep according to a complex level of productivity, such characteristics as the degree of contamination of the external and internal zones of the staple do not have clearly defined breeding differentials. Increased indicators of the content of mineral impurities in the wool of the best ewes by the rank of breeding purpose were established.

The insufficient level of hereditary capabilities to combine high protective fleece characteristics in the best ewes in terms of the complex level of productivity should be recognised as a disadvantage of the studied flock. The use of this technique allowed forming a unique group of sheep (5% of the herd) to produce outstanding breeding rams. The rank system for evaluating and selecting Merino allows effectively using the gene pool of the sheep population for breeding purposes. The issue of reducing the cost of sheep production by improving production technology and significantly improving domestic sheep breeds in terms of the quality of wool and meat products remains relevant. The prospects for further study are to investigate important components of the qualitative properties of wool quality properties in mutton sheep (using this technique) to successfully implement the process of improving the sheep flock as a whole.

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Conflict of Interest

None.

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Захисні властивості руна вівцематок таврійського типу асканійської тонкорунної породи залежно від рангу селекційної диференціації

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Анотація. Дослідження факторів, що впливають на вологість і забрудненість зовнішньої і внутрішньої зон штапелю, що в подальшому впливає на вихід чистої вовни і її технологічні властивості належить до актуальних проблем тонкорунного вівчарства. Мета дослідження – оцінка захисних властивостей руна вівцематок залежно від рангу селекційної диференціації овець. В основу визначення рангів покладено закономірності нормального розподілу тварин в популяції і показники відтворення стада. Використано 10 рангів. У статті наведено результати лабораторного дослідження вмісту мінеральних домішок і ступеня забруднення штапелю. Проведено розподіл вівцематок на 10 рангів селекційної диференціації. Враховано закономірності нормального розподілу тварин у популяції. Одержані дані свідчать, що різноманітність вівцематок за показниками вмісту мінеральних домішок у вовні дуже велика. Коефіцієнт варіації складає 35 % з коливанням за рангами селекційної диференціації від 13,7 до 38,4 %. При підвищенні групи загальної цінності овець за племінним призначенням величина коефіцієнта варіації зменшується ($r_s = -0,871 \pm 0,245$). При зростанні рангів селекційної диференціації середні абсолютні показники забруднення зовнішньої зони штапелю мають тенденцію до збільшення ($r_s = +0,257 \pm 0,483$), а відносні – зменшуються ($r_s = -0,600 \pm 0,400$). Середній абсолютний показник забруднення внутрішньої зони штапелю складає 3,02 см з коливанням за рангами від 2,83 до 3,29 см. За відносним ступенем забруднення ці показники складають відповідно 32,5 % і від 31,0 до 35,2 %. При зростанні рангу селекційної диференціації вівцематок абсолютні показники забруднення довжини внутрішньої зони штапелю збільшуються ($r_s = +0,600 \pm 0,400$), а відносні мають тенденцію до зменшення ($r_s = -0,486 \pm 0,437$). Індивідуальна різноманітність вівцематок за ступенем забруднення внутрішньої зони штапелю досить висока. Коефіцієнти варіації за абсолютними і відносними показниками цієї ознаки складають відповідно 28,5 і 30,4 %.

Величина коефіцієнтів варіації дещо зменшується при зростанні рангів селекційного призначення тварин. Рангова кореляція складає за абсолютними показниками $-0,371 \pm 0,464$ і відносними – $-0,543 \pm 0,420$. Селекційні диференціали провідних груп вівцематок невисокі. Використання даної рангової методики дозволяє контролювати систему оцінки тварин в процесі бонітування овець, доповнювати її величиною селекційних диференціалів на підсумкових етапах аналізу та відбору; у виробничих умовах формувати технологічні групи вівцематок для одержання видатних баранів-плідників

Ключові слова: мериноси; вівці; вміст домішок; ступінь забруднення; штапель; чиста вовна



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Growth and meat productivity of bulls depending on the similarity of their blood group B antigens with mothers

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Abstract. Various molecular genetic markers are used to comprehensively assess the breeding value of animals based on genetic information. Therefore, an important place in the qualitative improvement of beef cattle breeds is occupied by the improvement of methods of animal selection using the immunogenetic characteristics of their blood. The purpose of the study is to determine the dependence of weight growth and meat productivity of animals of the Ukrainian beef breed on the number of similar antigenic factors of the B blood group system in them and their mothers. After weaning, the first group contained bulls ($n = 12$) who had similar antigens from 2 to 6 inclusive. The second group ($n = 15$) – from 7 to 13. When studying the features of weight gain and meat productivity of bulls, it was proved that the similarity in the B system of cattle blood groups between mother and offspring is informative regarding the homo- or heterozygosity of the latter. It was found that animals with a lower amount of antigens similar to the mother outperformed (by 9.3%) homozygous peers in the test from 8 to 18 months of age in terms of average daily weight gain and had a higher live weight (by 8.0%) at 18 months, indicating their better early maturity. With lower antigenic similarity between mother and offspring, the expression of meat forms is 7.8% and 6.0% higher, respectively, at 15 and 18 months of age.

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After slaughter, there is no significant difference between homozygous and heterozygous bulls in terms of meat productivity, including pre-slaughter live and slaughter weight. When selecting offsprings with fewer antigens similar to their mother, they tend to reduce the slaughter yield (by 0.5 points) and the muscle content in carcasses (by 3.2%). The selection of bulls of Ukrainian beef breed with a smaller number of antigens of the B blood group system, similar to mothers, will help to improve their weight growth and the expression of meat forms, and will allow predicting future meat productivity

Keywords: breeding; live weight; average daily increment; Ukrainian beef breed; cattle breeding

Introduction

In the genetic progress of cattle of local breeds, the substantiation of animal breeding methods is of great importance. They are selected in a variety of ways, including by telomere length measured in white blood cells, as they are associated with health, ageing, and stress (Ilska-Warner *et al.*, 2019), genomic selection (Gutierrez-Reinoso *et al.*, 2021) and epigenetic regulatory mechanisms (Wang & Ibeagha-Awemu, 2021).

The productivity of offspring depends on the compatibility of parents for antigens of the B blood group system. Studies on animals of the Ukrainian beef breed indicate ambiguous results of the relationship between the similarity of parents by blood group factors and the offspring productivity. Thus, it is proved that bulls that are descended from their parents with a larger r_{as} predominate in terms of average daily increments and have a larger live weight. If r_{as} in parents is more than 0.268, animals tend to improve their growth rate by the age of 8 months (Ugnivenko & Natalych, 2021). This trend continues after weaning. In bulls received from parents with r_{as} up to 0.267, average daily increments are better in the period from 15 to 18 months, which indicates a lower precocity. According to the index of antigenic similarity of parents over 0.268, animals are better in the expression of meat forms at the age of 15 and 18 months. At 15 months, bulls obtained from

homogeneous selection, according to r_{as} , have lower height measurements, a better developed front part of the body in terms of chest width and depth, and a longer torso and backside. According to the homogeneous selection of fathers in their offsprings, in comparison with peers from heterogeneous mating, there is a tendency to increase the content of muscle (by 4.2%), adipose tissue in carcasses (by 12.4%), including between muscles (by 1.1 points) (Ugnivenko & Natalych, 2022). Per kilogramme of bones, the boneless meat is 11.6% less, the muscle tissue index is 17.2% worse, the absolute weight of the liver is 7.8% less, the kidneys are 10.0% less, the heart is 27.8% less, the head is 2.0% worse, and the lungs are 11.6% less. In bulls from a heterogeneous selection of parents with r_{as} up to 0.267, there is 7.2% more adipose tissue in the body, including 7.8% more internal tissue, and the relative weight of bones is 0.8 points higher. For sheep of the Kazakh meat-wool semi-fine-fleeced breed, the erythrocyte antigen Ab is informative, which correlates with a large shearing of wool (Islamov *et al.*, 2020). Among sheep of wool and coarse-wool types, carriers of B-factor blood groups showed an increase in the level of wool productivity.

According to the genetic mechanism of these relationships, alleles are influenced by the heterotic state, since the similarity between

the body of the offspring and the mother in terms of antigens affects their differences and determines the degree of compatibility or heterospecificity.

The problem of growth and meat productivity of offspring with different amounts of antigens of the B blood group system in them and mothers is not sufficiently studied. Information on the characteristics of meat productivity in bulls of local breeds that have different similarities with their mothers in terms of antigens is useful and necessary for the efficient and targeted production of beef and its valuable components. The purpose of the study is to determine the influence of the number of similar B blood group antigens in mothers and offsprings on their weight growth and meat productivity in Ukrainian beef cattle.

Materials and Methods

The analysis of the growth and meat productivity of bulls of the Ukrainian beef breed for different amounts of antigens of the B blood group system in them and their mothers were carried out in 2021 based on the materials of breeding accounting and production activities of the breeding plant “Volya” in Cherkasy oblast. Up

to 6-7 months of age, they were reared on suckling cows. After weaning, well-developed bulls were tested for the likelihood of origin by blood type factors. For this purpose, bovine erythrocyte antigens were used according to the blood group B system published (Podoba *et al.*, 1987) in the catalogue “Blood types of breeder bulls and cows used in the breeding of dairy and beef breeds of cattle”. Bulls were selected in 2 groups. The first group included animals (n = 12) according to the number of erythrocyte antigens of the B blood group system in them and their mothers from 2 to 6. In the second group (n = 15), the number of erythrocyte antigens ranged from 7 to 13. Intensive growing of bulls was carried out from 8 to 18 months of age according to diets compiled in accordance with the norms. The tests were carried out indoors on a tethered system. The feed eaten by each bull was counted every ten days for two consecutive days, weighing before feeding the animals, and its remains – after. The actually consumed feed was used to calculate its energy value (in oat fodder units) and costs per 1 kg of live weight gain. There was no significant difference in feed consumption between the bull groups (Table 1).

Table 1. Feed intake from 8 to 18 months of age by bulls who have different similarities with their mothers in terms of blood group factors of the B system

Feed	Group 1		Group 2	
	fodder units	%	fodder units	%
Concentrated	1.542 ± 121.0	50.9 ± 0.98	1.468 ± 95.8	47.7 ± 0.73
Coarse	363 ± 38.4	12.0 ± 1.22	454 ± 98.5	14.1 ± 2.37
Succulent	468 ± 53.4	15.4 ± 1.88	530 ± 83.4	16.8 ± 1.84
Green	657 ± 119.6	21.7 ± 2.55	634 ± 93.8	21.4 ± 3.56
Total	3.030 ± 216.1	100.0	3.086 ± 210.3	100.0

Meat forms in animals were evaluated in accordance with guidelines (Lukash & Shevchenko, 1983). At the end of the test at the age of 18 months, two groups were formed for

animal slaughter using the balanced analogue group method. The difference between them in live weight and age did not exceed 5%. During the experiment, the animals were kept in

accordance with the requirements of the Order of the Ministry of Agricultural Policy and Food of Ukraine, No. 652 (2012) and Guide for the Care and Use of Laboratory Animals (National Research Council..., 2011) and followed ARRIVE (2010) guidelines for reporting experiments on the use of live animals.

To determine the beef productivity of bulls, they were slaughtered in the Cherkasy meat processing plant in accordance with the requirements of DSTU 4673:2006 "Cattle for slaughter. Specifications" (2008). Before slaughter, animals were weighed before and after 24-hour fasting with free access to water and a pre-slaughter live weight was established. After slaughter, the slaughter weight (paired carcass) was determined by weighing. The slaughter yield (carcass) was calculated according to the ratio of the slaughter weight to the pre-slaughter live weight. The left semi-carcasses of the slaughtered bulls were deboned. Next, the weight of bones, muscle tissue, including the highest, first, and second grades, tendons and ligaments, and adipose tissue were weighed.

During the statistical processing of data, the average values (M) for groups, the statistical error of the average ($\pm m$), the difference between the means and its probability were determined according to the methods given in the paper (Osadcha, 2021). To characterise the variability of features, the variability coefficient (Cv , %) was calculated as the ratio of the mean square deviation to the average value for the group.

Results and Discussion

Bulls with different antigenic similarities with their mother did not differ in growth rate until 8 months of age. This was due to the milk consumed from their mothers, which offset the effect of selection by antigenic similarity on the growth rate of offspring during the suckling period. After weaning in different age periods, bulls tended to predominate in the number of similar antigens between them and mothers from 2 to 6 (from 4.6 to 15.3%) in terms of average daily increments over peers with 7 or more similar antigens (Table 2).

Table 2. Average daily increments of bulls with different numbers of similar antigens between them and mothers

Average daily increment for the period: from – to	Group 1			Group 2		
	<i>n</i>	<i>M</i> ± <i>m</i>	<i>Cv</i> , %	<i>n</i>	<i>M</i> ± <i>m</i>	<i>Cv</i> , %
0-8	12	912±39.7	14.4	15	914±29.7	12.2
8-12	12	1.221±75.8	20.6	15	1.145±42.3	13.8
12-15	12	1.266±92.0	24.1	13	1.210±71.3	20.4
8-15	12	1.246±51.6	13.7	13	1.185±43.0	12.6
15-18	7	1.140±118.5	25.5	9	988±119.7	34.2
8-18	7	1.258±61.4	12.0	9	1.151±37.1	9.1

A decrease in the number of erythrocyte antigens that the mother has in the offspring from 2 to 6 – with age increased the average daily increments in bulls compared to their peers with more than 7. At the age from 8 to 12

months, this difference was 6.6%, from 15 to 18 months – 15.3%.

Bulls with less similarity of antigenic factors of blood groups with their mother had greater variability in average daily increments

compared to their peers. This indicates that they do not adapt equally to environmental conditions, both before and after weaning. According to the coefficient of variation of the average daily weight gain, bulls between groups in all age periods did not have a significant difference. Heterozygous bulls in Group 1 grew faster for a longer time, maintaining a fairly high growth rate until the age of 18 months. Slowing of the growth rate from 15 to 18 months in homogeneous animals of Group

2 is associated with an increase in their precocity. A decrease in the differences between the mother's body and the offspring from 2 to 6 antigens accompanied an increase in live weight in bulls after weaning (Table 3). Thus, those with a number of antigens similar to the mother in the range from 2 to 6 tended to be 2.0% superior to their peers with the number of such antigens exceeding 7 by live weight at 12 months of age, 4.6% at 15 months of age, and 8.0% at 18 months of age.

Table 3. Live weight of bulls, with a different number of antigens similar to their mothers

Live weight by age: months	Group 1			Group 2		
	<i>n</i>	<i>M</i> ± <i>m</i>	<i>Cv</i> , %	<i>n</i>	<i>M</i> ± <i>m</i>	<i>Cv</i> , %
newborns	12	33.7 ± 0.66	6.5	15	32.4 ± 0.72	8.3
8	12	256 ± 9.7	12.6	15	255 ± 7.6	11.2
12	12	402 ± 13.7	11.3	15	394 ± 8.9	8.4
15	12	521 ± 11.4	7.3	14	498 ± 10.6	7.7
18	7	633 ± 17.3	6.7	10	586 ± 11.4	5.8

Thus, in the Ukrainian beef breed, the selection of heterozygous bulls with less similarity with mothers in terms of blood group factors led to an improvement in their average daily live weight gain. Similar features of the growth of homozygous and heterogeneous cattle by antigens of blood group factors were established by L.A. Koropets (2004). The level of similarity between the father and mother in terms of antigens affects the differences in them between the offspring and the body of the latter and determines one or another degree of their compatibility. It was found that an increase in differences between the mother's body and the offspring by blood group factors accompanies an increase in the live weight of bulls. Thus, in the group of bulls with the number of antigens absent from the mother in the range of 6-8, there was an increase ($P > 0.95$) in live weight by 9.1% at 18 months of age compared to their

peers with the number of antigens absent from the mother from 0 to 3. The comparison of indicators of signs of sperm productivity of bulls with heterospecificity by blood group factors indicates that an increase in the number of antigens in the offspring that are absent from the mother accompanies an improvement in the volume of ejaculate, sperm motility and its concentration.

The meat forms of bulls are different due to the unequal antigenic similarity between them and their mothers. In an animal with a larger value of this internal trait, the expression of meat forms at the age of 15 and 18 months is worse by 7.8% and 6.0%, respectively (Table 4). A smaller number of similar antigens between mother and offspring contributed to an increase in the propensity of offspring to early growth cessation and precocity, increased feed consumption for live weight gain by 12.7% from 8

to 18 months of age. Relatively more precocious cattle are less efficient for beef production due

to reduced meat productivity and higher energy costs for its production.

Table 4. The expression of meat forms and feed costs for live weight gain in bulls that have different antigenic similarities with their mothers

Meat forms (points) by age, months.	Group 1		Group 2	
	n	$M \pm m$	n	$M \pm m$
15	10	55.0 ± 0.86	9	51.0 ± 1.63
18	6	56.4 ± 0.99	9	53.2 ± 1.26
Feed costs per 1 kg of growth from 8 to 18 months, fodder units	7	7.9 ± 0.60	9	8.9 ± 0.90

In bulls with lower antigenic similarity with mothers compared to peers with greater

similarity, a slightly larger (by 1.1%) live weight was observed after a period of fasting (Table 5).

Table 5. Signs of slaughter and morphological composition of semi-carcasses in 18-month-old bulls that have different antigenic similarities with their mothers

Trait	Group 1			Group 2		
	n	$M \pm m$	Cv, %	n	$M \pm m$	Cv, %
Live weight after 24-hour fasting, kg	4	560 ± 24.2	7.5	5	554 ± 20.3	7.3
Slaughter weight (carcass), kg	4	350 ± 18.7	9.2	5	349 ± 13.5	7.7
Slaughter yield (carcass), %	4	62.5 ± 1.16	3.2	5	63.0 ± 0.74	2.3
Semi-carcass weight, kg	3	167 ± 11.9	10.1	4	165 ± 7.1	7.5
Bones, %	4	16.7 ± 0.64	6.7	4	16.6 ± 0.09	0.9
Muscle tissue, %	4	80.6 ± 1.37	3.0	4	80.4 ± 0.45	1.0
Including the highest grade, %	4	14.0 ± 1.84	17.0	4	18.8 ± 2.04	30.3
First grade, %	4	47.7 ± 2.33	10.9	4	43.0 ± 4.59	20.1
Second grade, %	4	38.3 ± 2.35	11.6	4	38.2 ± 2.45	13.9
Tendons and ligaments, %	4	2.7 ± 0.15	9.8	4	3.0 ± 0.18	12.0

Heterozygous bulls tended to increase (by 1.2%) the weight of semi-carcasses compared to homozygous peers. They were 4.8 points behind in terms of the content of the highest-grade muscle tissue, which does not include fat, tendons and ligaments. But they show a tendency to increase the relative amount (by 4.7 points) of first-grade boneless meat. In terms of the content of second-grade beef, which according to the sausage classification includes fat between muscles that is not separated during venation, there were no differences in bulls of different groups.

The influence of differences between the mother and offspring on the implementation of genetic information in the ontogenesis of the latter is attributed (Podoba, 1997) to the integral properties of the genome, which determine the effect of heterosis, non-specific resistance, and age-related changes (Shakhbazov, 1981). Within the pre-existing population, it was confirmed that bulls with less similarity to their mothers outperformed their peers with more similar antigens in terms of performance, due to the greater variability in variations of antigens received from the father.

Genetic variations in maternal and foetal loci affected placental formation, thereby determining the likelihood of a successful pregnancy outcome or the development of associated complications (Yeung & Dendrou, 2019). The mother's pregnancy affected their immune system and the foetus and the associated effects on stimulating its development. However, it was found that the different antigenic similarity between mothers and their offspring does not play a big role during the suckling period and before weaning. Bulls with genes involved in proteolysis, transcription, transport and immune functions, and oxidative processes differ in terms of live weight gain and feed intake (Lindholm-Perry *et al.*, 2017). This is comparable to the greater or lesser similarity of animals and their mothers in this experiment, which also affected average daily increments and feed consumption.

In the qualitative improvement of local cattle breeds, the practical use of interior features occupies an important place. Erythrocyte and white blood cell antigens, polymorphic systems, and DNA genome polymorphism are used to assess their breeding value based on genetic information that correlates with certain genes. Molecular genetic markers of an individual are formed during the embryonic period and do not change during its life, regardless of sex and age, physiological state, and are inherited according to Mendel's laws. Since the markers passed on to the offspring are closely interrelated with the loci that characterise performance traits, this allows labelling indicators. The priority area of research in the selection of beef breeds of cattle was to improve methodological approaches to the analysis of group factors to identify the features of their gene pool. Using B blood group factors, G.A. Tsilyuko (1987) evaluated the similarity and differences of structural units of the Ukrainian beef breed, determined the degree of

similarity between its successors and ancestors of lines, found out the relationship of immunogenetic markers with productivity, objectively evaluated the distribution of conditional frequencies of heredity of the original breeds in crossbreeds.

Due to the fact that mostly DNA markers are currently being studied in Ukraine, the use of blood group factors is experiencing a crisis. In recent years, studies have not found a significant link between beef cattle performance and blood group factors. For the most part, these results do not provide a large-scale improvement in the level of meat productivity of animals by breeding methods. The economy of cattle breeding is affected by the business output of offspring from mothers at the time of weaning 5 times more than the growth and 10 times more than the quality of carcasses (Minish & Fox, 1982). The mechanisms of formation of meat productivity in offspring under the influence of the mother's body at the molecular level are poorly studied. The application of conventional approaches using the antigenic similarity index of parents (r_{as}) does not fully provide solutions to problems related to the economy of beef cattle breeding. In this regard, the possibility of increasing beef production at the expense of the mother body, based on an understanding of the biological features of the inheritance of blood group factors of system B from cows by offspring, was of theoretical and practical importance. According to V.G. Nazarenko (1986), increasing the differences between the mother's body and the offspring in terms of red blood cell antigens reduces the embryonic period. Antigens absent in the mother, which characterise their incongruity with those present in the foetus, reflect certain trends in changes in the individual development of calves that are more heterozygous for this indicator (Tsilyuko *et al.*,

2000). In this study, it is manifested in the fact that bulls whose similarity to the mother was in the range of 2 to 6 antigens tended to prevail in live weight and meat forms over bulls whose similarity to their mothers was higher.

In this paper, cows and their offsprings were typed during weaning according to the factors of the B blood group of cattle to investigate the degree of similarity between them and its influence on the latter's productivity. A small similarity (from 2 to 6) in this trait between the genotypes of mothers and their offsprings descended from different bulls leads to an increase in the latter's level of heterozygosity by origin. This is the reason for the tendency to increase weight growth after weaning and signs of meat productivity in the offspring. Consolidation of animals closely related to their ancestors leads to a significant reduction in livestock biodiversity (Calabrese *et al.*, 2011), which was confirmed by this study as well. Mating of animals related by blood group factors, but not similar in phenotype and genealogy, counteracts the growth of homozygosity. Therefore, the probability of deterioration in productivity in offspring with low (from 2 to 6) similarity decreases. The preservation of heterozygosity by origin during such homogeneous mating should be explained by the presence of individuals satisfactory in terms of meat productivity among homozygous animals. In most cases, animals with heterozygous genotypes predominate homozygous in terms of meat productivity, which was confirmed in this study.

Thus, a comprehensive study and application of the compatibility of B blood group factors between mother and offspring, combined with productivity, will allow its further use for breeding heterozygous animals in herds of cattle of the Ukrainian beef breed and the provision of high-quality beef to the population.

Conclusions

Selection of bulls with a lower (from 2 to 6) similarity of erythrocyte antigens of the B blood group system between mother and offsprings compared to their peers with greater differences (7 to 13) leads to a tendency to increase heterozygosity in the latter and improve average daily increments and live weight after weaning from 2.0 to 8.0%, the severity of meat forms at 15 and 18 months, respectively, by 7.8 and 7.0%, and an increase in muscle content and the proportion of bone in the carcass. Compatibility between the genotypes of mother and son by antigenic factors decreases as their intake from the father's body increases and indicates an increase in the heterozygosity of the offspring. The lower similarity of the offspring by the antigens of erythrocytes of the B blood group system with the maternal genotypes, which leads to an increase in the level of heterozygosity in the offspring and to the improvement of their meat productivity, including the morphological composition of carcasses, indicates the expediency of using these immunological relationships in breeding. When selecting offspring for fattening, their similarity to the mother's genotype by blood group factors of System B should be taken into account, which will lead to an increase in their heterogeneity and contribute to an improvement in their live weight and average daily increments.

The prospect of further study is to investigate meat productivity, including offal, in animals obtained from different similarities in antigens with the maternal genotype, which would deepen knowledge about the methods of selection by origin in populations of beef cattle that are genetically diverse in pedigree and relatively homogeneous in internal characteristics. They will be relevant and timely, as they would allow identifying genetic and biological reserves for increasing the beef productivity of cattle with the rational use of its genetic potential.

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Conflict of Interest

None.

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Ріст і м'ясна продуктивність бугайців залежно від подібності їх антигенів системи В груп крові з матерями

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Анотація. Для всебічного оцінювання племінної цінності тварин на основі генетичної інформації використовують різноманітні молекулярно-генетичні маркери. Тому, важливе місце у якісному поліпшенні м'ясних порід великої рогатої худоби посідає удосконалення методів добору тварин за використання імуногенетичних характеристик їх крові. Метою роботи є визначення залежності вагового росту і м'ясної продуктивності тварин української м'ясної породи від кількості подібних антигенних факторів системи В груп крові у них та матерів. Після відлучення у першу групу включили бугайців (n = 12), у яких було подібних антигенів від 2 до 6 включно. У другу (n = 15) – від 7 до 13. Під час вивчення особливостей вагового росту і м'ясної продуктивності бугайців, доведено, що подібність за системою В груп крові великої рогатої худоби між матір'ю і приплодом є інформативною щодо гомо- чи гетерозиготності останніх. Встановлено, що тварини за меншої кількості подібних із матір'ю антигенів переважають (на 9,3 %) на випробуванні від 8- до 18-місячного віку гомозиготних ровесників за середньодобовими приростами і мають у 18-місяців більшу (на 8,0 %) живу масу, що свідчить про їх кращу скороспілість. За меншої подібності антигенів між матір'ю і приплодом у нього у віці 15 та 18 місяців кращою є вираженість м'ясних форм відповідно на 7,8 % та 6,0 %. Після забою між гомозиготними і гетерозиготними бугайцями вірогідної різниці немає за м'ясною продуктивністю, у.т.ч. передзабійною живою і забійною масою. За добору синів із меншою кількістю подібних із матір'ю антигенів у них проявляється тенденція до зменшення (на 0,5 пункти) забійного виходу та (на 3,2 %) вмісту м'язів у тушах. Добір бугайців української м'ясної породи за меншої кількості антигенів системи В груп крові, подібних з матерями сприятиме поліпшенню їх вагового росту та вираженості м'ясних форм і надасть можливість прогнозувати майбутню м'ясну продуктивність

Ключові слова: селекція; жива маса; середньодобовий приріст; українська м'ясна порода; скотарство



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Development of technology for plant-based minced semi-finished products

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Abstract. A healthy diet is the key to longevity, increasing the body's resistance to adverse environmental influences, and is a prerequisite for quality of life. One of the problems that humanity must solve today is the search for non-traditional protein sources and their popularisation in the food market as a healthy alternative to meat protein, which is the most popular. Nowadays, vegetarianism is the most widespread system of health-improving nutrition. According to this system, meat products (pork, beef) are replaced from the daily diet and other sources of amino acids take their place. The relevance of the study is related to the need to develop minced semi-finished products suited for consumption by a wide range of consumers, including those who adhere to vegetarian and vegan diets. The main goal of the study was to achieve the nutritional value of the protein component of minced meat compared to beef-based minced meat. The following research methods were used to solve these tasks: the organoleptic assessment considered: appearance, colour, cutaway view, smell, taste; moisture content – by drying the sample to a constant weight; fat content – by Soxhlet method; protein content – by Kjeldahl method; amino acid composition – by liquid chromatography, fatty acid composition – by gas-liquid chromatography. The main ingredient with protein content in minced meat is protein-wheat texture, which contains a balanced set of amino acids. The study of the amino acid composition of meatless minced semi-finished products has shown that this product is a valuable source of all essential amino acids. Cutlets are characterized by a significant content of valine, methionine, and phenylalanine. The finished product meets the requirements of the current regulatory documentation and does not pose a microbiological danger to the consumer. Therefore, the development of a new semi-finished product technology, which is a meatless minced meat composition that meets the requirements of a healthy diet in terms of protein and fat composition, is one of the ways to solve the problem of introducing food products recommended for vegetarians

Keywords: minced meat; protein; soy-wheat texturate; amino acids; hydration; fatty acids; healthy eating

Introduction

Nutrition is one of the most important environmental factors that directly affect the human body throughout its life. Biological components of food, which in the process of metabolism turn into structural and functional elements of the body's cells, ensure their physiological and psychological performance, adaptability, and immune status, and determine the state of human health, life expectancy, and social and personal activities. Therefore, the defining feature of the current stage of social development is that the problem of protecting the health of the population and extending the life expectancy of each person is no longer at the center of

attention only in biology and medicine, but also significant progress has been made beyond these sciences (Nazarenko & Ustymenko, 2023).

The human condition, as defined by the World Health Organisation, is "a state of complete physical, mental, and social well-being", and not just the absence of diseases (Li *et al.*, 2018). Despite this, the foundations of the healthcare system are focused on the organization of a healthy lifestyle, the main advantages of which are considered to be (Bal-Prylypko *et al.*, 2022):

- longevity;
- high physical performance;
- increased mental and business activity.

- resistance to the occurrence and development of diseases;

- prevention and resistance to obesity.

Each of these factors allows for increasing life expectancy by about two years. Vegetable raw materials are of great importance in human nutrition as a dietary product rich in vitamins, contributing to normal metabolism. When it comes to finding healthy food, most people today are not content with official or traditional views but constantly find their way. This has led to the emergence of many alternative nutrition systems (Ivaniuta *et al.*, 2021). Among them, the most important is a rational diet, depending on age, gender, level of physical activity, and intake of all the necessary substances with food, the number of which is close to 70 (Holembovskaya *et al.*, 2021). Of these, carbohydrates, fats, and proteins play an important role in regulating the body's metabolic and energy processes, the sufficiency and usefulness of which determine the health status of the average consumer by 68-74% (Bal-Prylypko *et al.*, 2022).

Among the main types of healthy eating, the most common are vegetarianism, separate meals, and raw food. Today, the vegetarian menu is also gaining popularity in restaurant establishments (Tolok, 2018). Various aspects of the development of the food system – vegetarianism and the activities of vegetarian institutions are covered by such researchers as: G.A. Tolok (2018), M.V. Buzhanska (2022), and M.V. Skobenko *et al.* (2022). Consideration of the papers by the above-mentioned researchers allows for taking a meaningful approach to the analysis of the scientific task set, identifying issues that remain relevant.

In the next 10 years, the market for plant-based alternatives will occupy 10% of the global meat market. The number of Ukrainians who gave up meat, the most successful young people, has reached 2 million and continues to

grow (Bal-Prylypko *et al.*, 2022). Conscious consumers take a thoughtful approach to nutrition and understand the impact of their choices on the health of both themselves and the planet. The absence of allergens in food, “clean labels”, and “eco-friendly products” are not all that concern the modern consumer. Being picky means not only choosing products with a healthier list of ingredients, but also paying attention to packaging, production methods, consumption, processing, and delivery methods (Onwezen, 2021). Therefore, the main goal in developing the technology of plant-based minced semi-finished products was to achieve the nutritional use of the protein component of plant-based minced meat in comparison with beef-based products.

Literature Review

Considering the arguments in favor of limiting meat consumption and a significant increase in the cost and shortage of animal products, the task arose to develop recipes for meatless minced cutlets. The main task was to rationally plan the complete replacement of animal protein with vegetable protein by including it in the composition of products that would contain a set of amino acids close to the characteristics of meat (Ivaniuta *et al.*, 2021). The problem statement, in addition to solving the issue of reducing environmental pressure on the environment while reducing the caloric content of the product, is conditioned by the need to expand the range of consumers to include people who adhere to vegetarian nutrition principles.

Among the ingredients of food products, proteins play a decisive role in the normalization of plastic and partial energy processes (Bal-Prylypko *et al.*, 2023). The body's need for protein depends on the age of the individual. The recommended amount of protein, depending on age, is shown in Table 1.

Table 1. Protein requirements of the body

Consumer category	The recommended amount of protein, grams per day	
	total	including animal
Children under 1-year-old	up to 3	up to 2.5
Children 1-5 years old	53-65	33-37
Children 6-10 years old	72-78	36-39
Children 11-17 years old	83-104	42-52
Adult men	102-107	53-59
Adult women	78-84	43-46

Source: (Ihnatenko, 2019)

In recent years, researchers have proven the expediency of fulfilling the protein deficiency in the human diet by using vegetable protein. The majority of published studies (Bal-Prylypko *et al.*, 2022) state that the predominance of animal protein in the diet is associated with the proximity of its amino acid composition to the physiological needs of humans, and meat, eggs, and poultry are considered the best sources of its production. At the same time, one of the main conditions for a healthy diet is considered to be maintaining a ratio close to 1:2 by weight in the protein component of the content of essential and non-essential amino acids.

However, the use of raw meat in consumer goods has many disadvantages. First of all, a large group of supporters of vegetarianism remains outside the consumer group. Moreover, significant problems should include the ingress of waste products into the natural environment when raising domestic animals. According to N.V. Novhorodska *et al.*, (2021) “a farm with 2,500 animals that give milk creates as much waste as a city with a population of 411 thousand people.” In addition, the share of carbon dioxide generated in the process of growing fodder crops, harvesting, processing, and transportation of feed and meat made from them reaches 9% on a global scale. Moreover, according to the UN, raising and keeping domestic animals is accompanied by the generation of up to 18% of global greenhouse gas emissions –

methane, ammonia, and nitrogen monoxide, which is significantly more than land, sea, and air transport, which accounts for only 13% of their total amount (Eveleva *et al.*, 2019).

No less important arguments in favor of finding alternative sources of food protein production are that pastures used by humanity in raising animals occupy up to a third of the areas suitable for farming, and the amount of water consumed by industrial technologies to obtain, for example, 1 kilogram of beef requires about 15 thousand liters of water. Less water-intensive is the production of other types of meat: 6 thousand liters for pork, 4,300 liters for chicken, while the production of, for example, 1 kilogram of soy requires 2 thousand liters, wheat – 1 thousand, potatoes – 100 liters (Shugang *et al.*, 2017).

Materials and Methods

The research was conducted to complete the tasks set according to the established relevant standard methods: the organoleptic assessment considered: appearance, colour, cutaway view, smell, and taste according to DSTU 4437:2005 (2007) “Semi-finished meat and meat-vegetable minced products”; moisture content – by drying according to DSTU ISO 1442:2005 (2007) “Meat and meat products. Method for determining the moisture content”; the number of proteins was determined according to GOST 25011-2017 (2018) “Meat and meat products. Methods of protein determination”;

the amount of fat was determined by DSTU 8380:2015 (2017) “Meat and meat products. Method for measuring the mass fraction of fat”; the amino acid composition was determined by liquid chromatography using an amino acid analyzer “BIOTRONIK” (Germany); the fatty acid composition was determined by gas-liquid chromatography using an Automated Gas Chromatograph “Kupol-55”; microbiological indicators of finished products were determined by DSTU 4437: 2005 (2007) “Semi-finished meat and meat-vegetable minced products”, the total caloric value was calculated from the sum of values for 100 g of product, based on the following ratios: 1 g of protein – 4 kcal (16.7 kJ), 1 g of fat – 9 kcal (37.7 kJ), 1 g of carbohydrates – 3.75 kcal (15.7 kJ).

The ingredients used for the preparation of semi-finished products required special preparation methods. The main condition was to achieve uniformity of emulsions, the prerequisite for which is the transfer of solid ingredients (soy-wheat texture, methylcellulose) to the state of an emulsion. This is the

fundamental difference between the preparation of plant raw materials, which, unlike meat raw materials, require pre-hydration. This action, as well as work on preparing for the use of other ingredients in minced meat, was performed as follows.

Soy-wheat texture, which contained 10% adsorbed water, was mixed with three parts cooled to 4°C water and at a speed of 60 rotations of the frame agitator per minute, stirred for 20 minutes until uniformity. Methylcellulose was used as an additive designed to bind fat and prevent the delamination of minced meat mixtures. To transfer it to the emulsion state, powdered methylcellulose was mixed with 2% sunflower oil, and a water-ice mixture was added to the system and mixed at a speed of 60 rotations of the frame agitator per minute until uniformity. The amount of water phase required for the mixture to achieve plasticity was varied to determine the optimal amount of water fraction. The ratio of components and properties of water-oil emulsions of methylcellulose are shown in Table 2.

Table 2. Component ratios and properties of methylcellulose water-oil emulsions

No.	Component ratio			State of the emulsion after homogenization	Emulsion consistency	Condition of hydrated fibers
	Methylcellulose	Sunflower oil	Water-ice mixture			
1	1	2	7	Rubber-like condition, high elasticity	High-density difficult mixing	Partial hydration, the presence of a solid phase
2	1	2	15	Dense structure, shape retention	Condition is similar to sour cream	Full hydration uniform condition
3	1	2	25	Stratification of the emulsion, the release of free moisture	Spreading of the emulsion without preserving its shape	Full hydration, availability of free moisture

Based on the comparison of the state of the emulsions, a choice was made in favor of experiment No. 2, because the selected ratio of components provided a dense consistency

and preserved the shape. The prepared ingredients were mixed in a cutter with the remaining components of the minced meat mixture in an arbitrary sequence. In the period from

February 2021 to February 2022, following the requirements of DSTU 4437:2005 (2007), many tastings of cutlets based on plant raw materials were conducted among vegans aged 18 to 53 years, as well as among consumers who adhere to a traditional diet, and about 150 reviews were processed. Studies were also conducted among the meat-consuming population, who tasted cutlets based on meat and plant raw materials. Indicators of appearance, cutaway view, color, taste, aroma, consistency, and juiciness were evaluated on a five-point scale. Works with human participants following the principles set out in the Helsinki Declaration

The organoleptic assessment was carried out in 3 stages:

1. Tasting of plant-based semi-finished products in their pure form (simple heat treatment, without sauces and side dishes)
2. Tasting of plant-based semi-finished products in ready meals (burgers).
3. Tasting of plant-based semi-finished products as a filling for complex dishes, with the addition of other flavor components (ravioli, dumplings).

Results and Discussion

Comparative studies of beef proteins and soy and wheat textures to a certain extent refute the myth of the essential nature of animal protein and show close similarity in the amino acid

composition of all three sources, especially in terms of obtaining the necessary complex of amino acids with plant-based meat substitutes: industrial batches of both soy and wheat texture according to their content, including those that the body is not able to synthesize, can be considered as its healthy replacement in minced meat mixtures. Therefore, it was concluded that it is advisable to develop recipes for minced plant-based products as an alternative to minced meat containing animal protein.

The second most protein-rich component of minced cutlet mixes is fat. Sunflower oil is traditionally used in this capacity in Ukrainian national cuisine, provided that animal fat is avoided. However, its chemical composition does not meet the existing dietary guidelines for the ratio of omega-6 and omega-3 fatty acids. Their mass fractions in oil are $48.3 \div 74.0\%$ and 0.3% , respectively (Table 3), while in the optimum their ratio is in the range from 1:2 to 1:4. The consequences of this discrepancy can be an increase in blood viscosity and a tendency for excessive clotting, which can lead to blood clots and high blood pressure. In part, this ratio may be close to the recommended dosage reduction of sunflower oil in minced meat and the introduction of coconut oil in it instead, the composition of which is shown in Table 3 in comparison with the composition of sunflower oil.

Table 3. The fatty acid content in sunflower and coconut oils, %

Fatty acid	Oilseed crop	
	Sunflower	Coconut
Lauric (C12)	up to 0.1	43.0-51.0
Myristic (C14)	up to 0.2	16.0-21.0
Palmitic (C16)	5.0-7.6	7.5-10.0
Palmitoleic (C16)	up to 0.3	0.2-1.5
Stearic (C18)	2.7-6.5	2.5-4.0
Oleic – ω -9 (C18)	14.0-39.4	5.0-10.0
Linoleic – ω -6 (C18)	48.3-74.0	1.0-2.5
Linolenic – ω -3 (C18)	up to 0.3	up to 0.5

Table 3. Continued

Fatty acid	Oilseed crop	
	Sunflower	Coconut
Arachidic (C20)	0.1-0.5	up to 0.5
Gadoleic (C20)	up to 0.3	up to 0.5
Behenic (C22)	0.3-1.5	up to 0.5
Erucic (C22)	up to 0.3	up to 0.5
Docosadienoic (C22)	up to 0.3	n/a
Lignoceric (C24)	up to 0.5	up to 0.5

An additional argument in its favor is that coconut oil is rich in myristic acid, which is extremely important for strengthening memory, which is practically absent in sunflower and olive oils widely used in such recipes (Wu *et al.*, 2018).

Based on the benefits of replacing the meat component with vegetable textures, given the traditional set of additives to minced meat and the

norms of their use, a recipe for a chopped minced product that does not contain a meat component was developed (experiment). Dietary minced meat based on the use of beef that meets the requirements of the national standard DSTU 4437-2005 (2007) was selected as a control comparison sample. Recipes for minced meat (control and experimental samples) are presented in Table 4.

Table 4. Recipes for minced cutlets based on meat and plant raw materials

Recipe component	Mass fraction of the ingredient, %	
	Control	Experimental
Water	23.8	62.3
Beef cutlet meat	25.1	-
Sausage ridge fat	30.2	-
Soy-wheat texturate	-	21.0
Wheat flour bread	11.1	-
Breadcrumbs	4.0	-
Hydrolyzed vegetable protein	-	0.7
Dry potato or wheat fiber	2.0	-
Yeast extract	-	0.7
Table salt	1.2	0.7
Beetroot juice	-	1.0
Chopped onion	3.5	-
Coconut oil	-	6.3
Methylcellulose	-	2.0
Sunflower oil	-	5.0
Vegan flavoring AlmaMit C25/11	-	0.3
Ground black or white pepper	0.1	-

Nevertheless, the main criterion for the quality of minced meat in the proposed recipe is the usefulness of the amino acid composition of the protein component. The corresponding calculation was made because wheat

added to the control minced meat with the meat component contains about 12% protein in total, and its content in the added bread does not exceed 50 %. The calculation results are shown in Table 5.

Table 5. Amino acid composition of experimental and control minced meat products, g/100 g

Amino acid	Experimental	Control
Essential amino acids		
Valine	1.5	1.4
Isoleucine	1.1	1.1
Leucine	1.8	2.1
Lysine	0.9	2.1
Methionine	0.5	0.2
Threonine	0.7	1.2
Tryptophan	0.2	0.3
Phenylalanine	1.4	1.2
<i>Total essential amino acids</i>	<i>8.1</i>	<i>9.6</i>
Non-essential amino acids		
Alanin	0.9	1.5
Arginine	1.6	1.5
Aspartic acid	1.7	2.5
Histidine	1.0	1.0
Glycine	1.2	1.3
Glutamic acid	4.5	4.6
Proline	1.6	1.2
Serine	1.1	1.1
Tyrosine	0.8	1.0
Cystine	0.3	0.3
<i>Total non-essential amino acids</i>	<i>14.7</i>	<i>16.0</i>
<i>The total content of amino acids in the composition</i>	<i>22.8</i>	<i>25.6</i>

To calculate the caloric content of the product, the values of the corresponding characteristics of proteins at 16.75 kJ/g, fats at 37.5 kJ/g, and carbohydrates at 16.5 kJ/g

were used. The results of determining the chemical composition of samples of plant-based “meat” semi-finished products are shown in Table 6.

Table 6. Chemical composition of control and experimental samples of minced meat cutlets ($n=3$, $p \geq 0.95$)

Mass fraction of the component, %	Control	Experimental
Protein	17±0.1	16.7±0.1
Fat	10±0.04	9.78±0.04
Carbohydrates	0.7±0.03	5.35±0.03
Moisture	68.1±0.3	64.6±0.3
Table salt	1.3±0.1	1.52±0.1
Fibre	0	1.15
Caloric value, kJ	560 (133.8 kcal)	615 (146.6 kcal)

A comparative analysis of the chemical composition of semi-finished beef products

produced using conventional technology and with plant raw materials shows that plant-based

products are characterized by a high content of fats and carbohydrates and an insignificant decrease in protein content. Moreover, plant-based products are distinguished by the presence of fiber in their composition, which significantly improves intestinal function. To determine the compliance of the developed

composition with the requirements of sanitary and epidemiological safety in comparison with the control following the indicators of the national standard DSTU 4437-2005 (2007), the product was tested during the guaranteed shelf life (10 days from the date of manufacture). The test results are presented in Table 7.

Table 7. Results of determination of the level of bacteriological contamination of minced meat products of experimental and control composition

Product	Indicator of bacteriological contamination			
	Coliform bacteria in 0.1 g	<i>L.monocytogenes</i> in 25 g	<i>S.aureus</i> in 1 g	Pathogenic, incl. salmonella in 1 g
Control	Not Found	Not Found	Not Found	Not Found
Experimental	Not Found	Not Found	Not Found	Not Found

Analysis of the data in Table 7 shows that the microbiological indicators of the finished product met the requirements of the current

regulatory documentation on microbiological safety.

The data obtained are shown in Figure 1.

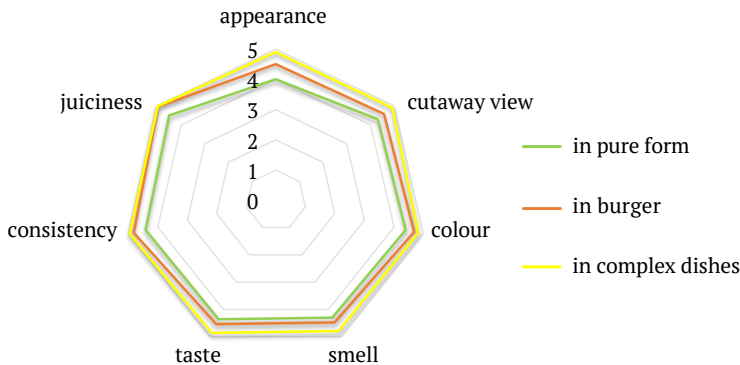


Figure 1. Results of evaluation of organoleptic parameters of minced semi-finished products of experimental and control composition

The results of the sensory analysis showed that plant-based semi-finished products such as minced meat and filling have the highest overall score in all indicators, based on which it was concluded that meatless minced semi-finished products on a plant basis can be recommended for general consumption both due to their nutritional value and compliance with the

established taste preferences of a wide range of consumers, including those who adhere to the norms of vegetarianism.

Conclusions

The properties of soy protein allow it to be actively used in the meat processing industry of the food industry. As for the production of

minced semi-finished products of plant origin, they are indispensable in the diet of people who do not consume animal proteins.

According to the study results, it was determined that the composition of the developed minced plant-based product is practically equivalent to the composition of minced meat from the standpoint of providing the body with proteins and meets the standards of healthy nutrition. It is shown that the developed meatless minced meat composition is close to the composition of traditional ground beef in terms of protein component composition and can be recommended for use in traditional diets. The finished product using the developed technology almost does not differ in consumer qualities from the meat product using conventional technology. The study of the amino acid composition of meatless minced semi-finished products has shown that this product is a valuable source of all essential amino acids. Cutlets are characterized by a significant content of valine, methionine, and phenylalanine.

Analysis of the chemical composition of semi-finished products made from beef using conventional technology and based on plant raw materials proves that plant-based products are characterized by a high content

of fats and carbohydrates and an insignificant decrease in protein content. Moreover, plant-based products are distinguished by the presence of fiber in their composition, which significantly improves intestinal function. The tasting committee noted that the consistency of the product is very similar to meat, and the cooking method allows for maintaining a traditional food culture. Tasting by meat eaters showed that there were no significant changes in the organoleptic properties of the product and people who consume meat will not feel uncomfortable when consuming a product that does not contain meat.

The developed technology of mincing semi-finished products will significantly expand the range of products for people who adhere to vegetarian and vegan standards of phytonutrients, which will somewhat mitigate the current problems of healthy eating. The positive research findings indicate that this technology should be further studied and requires further development.

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None.

Conflict of Interest

None.

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Розробка технології січених напівфабрикатів на рослинній основі

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Анотація. Здорове харчування є запорукою довголіття, підвищення стійкості організму до несприятливих впливів довкілля, є умовою якості життя. Однією з проблем, яку сьогодні мусить вирішувати людство, є пошук нетрадиційних джерел білка, а також їх популяризації на продуктовому ринку як здорової альтернативи м'ясному білку, який користується найбільшою популярністю. На сьогодні вегетаріанство є найбільш широко розповсюдженою системою оздоровчого харчування. За цією системою з повсякденного раціону витісняють м'ясні продукти (свинину, яловичину) і на місце їм приходять інші джерела амінокислот.

Актуальність роботи пов'язана з необхідністю розробки фаршевих напівфабрикатів дозволених до вживання широким колом споживачів, включаючи осіб, які дотримуються вегетаріанських та веганських норм харчування. Основною метою досліджень було досягнення харчової повноцінності білкового компоненту фаршу у порівнянні з фаршами на основі яловичини. Для вирішення поставлених завдань використовували такі методи досліджень: при органолептичній оцінці враховувалися: зовнішній вигляд, колір, вид на розрізі, запах, смак; вміст вологи – методом висушування зразка до постійної маси; вміст жиру – методом Сокслета; визначення вмісту білка – методом К'ельдаля; амінокислотний склад визначали методом рідинної хроматографії, жирнокислотний склад визначали методом газорідинної хроматографії. Основним інгредієнтом із вмістом білка у фарші використаний білково-пшеничний текстурат, який містить збалансований набір амінокислот. Вивчення амінокислотного складу безм'ясних подрібнених напівфабрикатів показало, що цей продукт є цінним джерелом усіх незамінних амінокислот. Котлети характеризуються значним вмістом валіну, метіоніну й фенілаланіну. Готовий продукт відповідає вимогам чинної нормативної документації та не становить мікробіологічної небезпеки для споживача. Тому розробка технології нового напівфабрикату, яка являє собою безм'ясну фаршеву композицію, за складом білкового та жирового компоненту відповідає вимогам здорового харчування, є одним із шляхів вирішення проблеми впровадження харчових продуктів, які рекомендовані для вегетаріанців

Ключові слова: фарш; білок; соєво-пшеничний текстурат; амінокислоти; гідратація; жирні кислоти; здорове харчування

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