IRSTI 65.59.15 **https://doi.org/10.58805/kazutb.v.4.25-675**

POTENTIAL OF CHICKEN PROCESSING BY-PRODUCTS IN COLLAGEN PROTEIN HYDROLYSATE PRODUCTION BASED ON DISTAL LIMBS AND STOMACHS

T. Tultabayeva✉, K.Makangali, G. Tokysheva, A. Shoman, D. Aiken

NJSC «S.Seifullin Kazakh agrotechnical research University», Astana, Kazakhstan

✉Corresponding-author: tultabayeva@inbox.ru

This study investigates the feasibility of producing collagen protein hydrolysates from chicken processing by-products, specifically distal limbs and stomachs, which are often treated as waste in the poultry industry. With the increasing demand for sustainable and functional ingredients, these by-products offer a valuable source of bioactive proteins, including collagen, that can be transformed into protein hydrolysates for use in the food industry. The research evaluates key physical and chemical properties, including water-binding capacity, shear stress, viscosity, and protein digestibility, to determine the suitability of distal limbs and stomachs for hydrolysate production. Using structural analysis, we measured the mechanical resistance and structural stability of these by-products, with findings showing that distal limbs have a high collagen content (11.3%) and excellent water retention, while stomachs exhibit lower fat content (2.1%) and high protein concentration (21.4%), making both suitable for hydrolysis. Viscosity and shear stress tests further support the use of these materials, indicating stability and strong structural integrity under processing conditions. Additionally, protein digestibility studies suggest that collagen hydrolysates from these sources may have enhanced bioavailability. The results suggest that utilizing distal limbs and stomachs for collagen hydrolysate production is a viable approach to create functional, high-protein food ingredients while also addressing sustainability by reducing waste. By transforming these by-products, the poultry industry can contribute to circular economy practices, enhance resource efficiency, and promote eco-friendly food production. This research underscores the potential for incorporating collagen protein hydrolysates from poultry by-products into various food applications, presenting both economic and environmental benefits.

Keywords: poultry by-products, sustainable food production, collagen protein hydrolysates, chicken stomachs, physicochemical properties.

ПОТЕНЦИАЛ ПОБОЧНЫХ ПРОДУКТОВ ПЕРЕРАБОТКИ ПТИЦЫ ДЛЯ ПРОИЗВОДСТВА БЕЛКОВЫХ КОЛЛАГЕНОВЫХ ГИДРОЛИЗАТОВ НА ОСНОВЕ ДИСТАЛЬНЫХ КОНЕЧНОСТЕЙ И ЖЕЛУДКОВ

Т.Ч. Тултабаева✉, К.К. Макангали, Г.М. Токышева, А.Е. Шоман, Д.К. Айкен

НАО «Казахский агротехнический исследовательский университет им.С.Сейфуллина»,
Астана, Казахстан,
e-mail: tultabayeva@inbox.ru

В данном исследовании изучается возможность производства коллагеновых белковых гидролизатов из побочных продуктов переработки курицы, в частности из дистальных конечностей и желудков, которые часто рассматриваются как отходы в птицеводческой отрасли. С ростом спроса на устойчивые и функциональные ингредиенты эти побочные продукты представляют собой ценный источник биоактивных белков, включая коллаген, которые могут быть превращены в белковые гидролизаты для использования в пищевой промышленности. В работе оцениваются ключевые физико- химические свойства, такие как влагосвязывающая способность, напряжение сдвига, вязкость и усвояемость белков, чтобы определить пригодность дистальных конечностей и желудков для производства гидролизатов.

С использованием структурного анализа были проведены измерения механической прочности и структурной стабильности побочных продуктов. Результаты показали, что дистальные конечности обладают высоким содержанием коллагена (11,3%) и отличной способностью удерживать влагу, в то время как желудки имеют низкое содержание жира (2,1%) и высокую концентрацию белка (21,4%), что делает оба материала подходящими для гидролиза. Испытания на вязкость и напряжение сдвига дополнительно подтвердили стабильность и высокую структурную целостность этих материалов в условиях обработки. Более того, исследования усвояемости белка показали, что коллагеновые гидролизаты из этих источников могут обладать улучшенной биодоступностью. Полученные результаты свидетельствуют о том, что использование дистальных конечностей и желудков для производства коллагеновых гидролизатов является перспективным подходом для создания функциональных, высокобелковых пищевых ингредиентов, а также способствует устойчивому развитию за счет сокращения отходов. Преобразуя эти побочные продукты, птицеводческая отрасль может внести вклад в практики циркулярной экономики, повысить эффективность использования ресурсов и поддержать экологически чистое производство. Данное исследование подчеркивает потенциал включения коллагеновых белковых гидролизатов из побочных продуктов птицеводства в различные пищевые продукты, предлагая как экономические, так и экологические преимущества.

Ключевые слова: побочные продукты птицеводства, устойчивое производство продуктов питания, коллагеновые белковые гидролизаты, куриные желудки, физико- химические свойства.

ҚҰС ӨҢДЕУ ҚАЛДЫҚТАРЫНЫҢ ДИСТАЛЬДЫ АЯҚТАР МЕН АСҚАЗАНДАР НЕГІЗІНДЕ КОЛЛАГЕНДІ АҚУЫЗ ГИДРОЛИЗАТЫН ӨНДІРУДЕГІ ӘЛЕУЕТІ

Т.Ч. Тултабаева✉, Қ.Қ. Мақанғали, Г.М. Токышева, А.Е. Шоман, Д.К. Айкен

«С.Сейфуллина атындағы Қазақ агротехникалық зерттеу университеті» КеАҚ, Астана қ.,
Қазақстан Республикасы,
e-mail: tultabayeva@inbox.ru

Бұл зерттеу тауық өңдеу қалдықтарынан, атап айтқанда дистальды аяқтар мен асқазандардан, коллагенді ақуыз гидролизаттарын өндіру мүмкіндігін зерттейді, себебі олар құс шаруашылығында жиі қалдық ретінде қарастырылады. Тұрақты және функционалды ингредиенттерге деген сұраныстың артуына байланысты, бұл қалдықтар биологиялық белсенді ақуыздардың, соның ішінде коллагеннің, құнды көзі болып табылады және оларды тағам өнеркәсібінде қолдануға арналған ақуыз гидролизаттарына айналдыруға болады. Зерттеу гидролизат өндірісіне жарамдылығын анықтау үшін су ұстау қабілеті, кесу кернеуі, тұтқырлық және ақуыздың сіңімділігі сияқты негізгі физикалық және химиялық қасиеттерін бағалайды. Құрылымдық талдау арқылы біз бұл қалдықтардың механикалық беріктігі мен құрылымдық тұрақтылығын өлшедік; нәтижелер көрсеткендей, дистальды аяқтарда коллагеннің жоғары мөлшері (11,3%) және суды жақсы ұстай алу қабілеті бар, ал асқазандардың майы аз (2,1%) және ақуыз концентрациясы жоғары (21,4%), бұл екеуін де гидролизге қолайлы етеді. Тұтқырлық пен кесу кернеуіне жасалған сынақтар бұл материалдардың өңдеу жағдайларында тұрақтылығын және құрылымдық тұтастығын растайды. Қосымша ақуыз сіңімділігіне жасалған зерттеулер осы көздерден алынған коллаген гидролизаттарының биожетімділігінің жоғары болатынын көрсетеді. Нәтижелер бойынша дистальды аяқтар мен асқазандарды коллаген гидролизатын өндіруде пайдалану қалдықтарды азайта отырып, функционалды, ақуызға бай тағамдық ингредиенттер жасау үшін тиімді тәсіл болып табылады. Бұл қалдықтарды өңдеу арқылы құс шаруашылығы айналмалы экономикаға үлес қосып, ресурстарды тиімді пайдаланып, экологиялық таза тағам өндірісін қолдай алады. Бұл зерттеу құс шаруашылығындағы қалдықтардан алынған коллаген гидролизаттарын әртүрлі тағам қолданбаларына енгізу әлеуетін көрсетеді және оның экономикалық әрі экологиялық пайдасын атап көрсетеді.

Түйін сөздер: құс өңдеу қалдықтары, тұрақты азық-түлік өндірісі, коллагенді ақуыз гидролизаттары, тауық асқазандары, физика-химиялық қасиеттер.

Introduction. Poultry farms play an essential role in modern agriculture, providing the population with vital food products, such as meat and eggs. These products are highly valued for their nutritional content, accessibility, and versatile culinary applications [1]. Poultry farms are capable of producing high-quality products with relatively minimal labor and resource inputs compared to other livestock sectors [2]. Poultry production is instrumental in ensuring food security, representing the fastest-growing segment of animal husbandry in many countries [3], with egg and poultry meat production meeting the needs of both rural and urban populations [4]. The production of eggs and poultry meat contributes to economic growth by generating employment opportunities across large enterprises and small to medium-sized farms [5] and supports smallholder operations that supply local communities with food [6]. In developed countries, poultry farming is leveraged to address national food security objectives by increasing the supply of valuable food resources like meat and eggs [7]. Beyond food provision, poultry farming is a critical tool in combating poverty and improving living standards in rural areas. In developing countries, poultry serves as an essential asset for impoverished households, providing income and food security [8]. Poultry production also promotes sustainable agricultural development by enabling efficient resource use and enhancing food security [9]. With the rising demand for poultry products, such as meat and eggs, many countries, including those still developing, face challenges in securing adequate resources for the sector [10]. Issues include environmental pollution due to waste and the consumption of natural resources for poultry feed [11]. However, in response to these challenges, many nations are working to develop more sustainable farming practices aimed at reducing environmental impacts [12]. Thus, poultry farms have a significant impact on food provision, economic development, and the improvement of living standards through job creation and enhanced food security.

In Kazakhstan, the poultry sector occupies a central position within animal husbandry, playing a crucial role in providing the population with socially significant food products, including poultry meat and eggs. Currently, the country has 69 poultry farms, comprising 34 for egg production, 29 for meat production, and 6 breeding farms. Additionally, Kazakhstan is expanding the capacity of four poultry farms to produce an additional 200,000 tons of poultry meat per year, which will satisfy domestic poultry meat demand and support export potential, as reported by the Prime Minister' s press service [13]. Specifically, the following farms will be funded: Canadian Chicken Limited in Akmola Region with an annual output of 12,500 tons, Alel Agro in Zhambyl Region with 25,000 tons, Prima Kus in Almaty Region with 35,000 tons, and Aitas KZ in Almaty Region with 120,000 tons. The projects will be financed by the Development Bank of Kazakhstan and implemented between 2025 and 2026. This indicates a sustained increase in production and processing costs, underscoring the need for process optimization and efficiency improvements in the poultry sector, along with exploring innovative ways to reduce production costs, including through secondary raw material utilization.

The objective of this study is to examine the secondary raw materials from poultry processing to justify their application in the production of protein hydrolysates.

Materials and methods. The subjects of this study encompassed chicken distal limbs and stomachs. Shear stress and viscosity of the meat raw material were meticulously assessed using the Structurometer ST2 (Lab Quality LLC, Russia) to analyze the mechanical properties of sausage products, such as shear resistance and viscosity.

Shear force measurements were conducted with the Structurometer ST2, which recorded force values F upon application to the sausage sample. Cross-sectional area A was quantified by measuring the blade-sample contact surface.

Shear rate γ was derived from sample characteristics and experimental conditions, with structurometer-generated data employed to calculate viscosity, providing insights into the raw material's resistance to deformation under shear load.

Water activity in the sausage products was evaluated using the Aqualab 4TE device (METER Group, USA), while chemical composition of the meat materials was precisely determined using the TANGO R spectrometer (Bruker, Germany), equipped with a pre-loaded calibration model to ensure accurate compositional analysis.

Results and discussion. The experiments were conducted using the Structurometer ST2 (manufactured by Labreactive, Russia), with all measurements performed in six replicates. To determine shear stress, the force and deformation of the meat samples were evaluated (Figures 1 and 2).

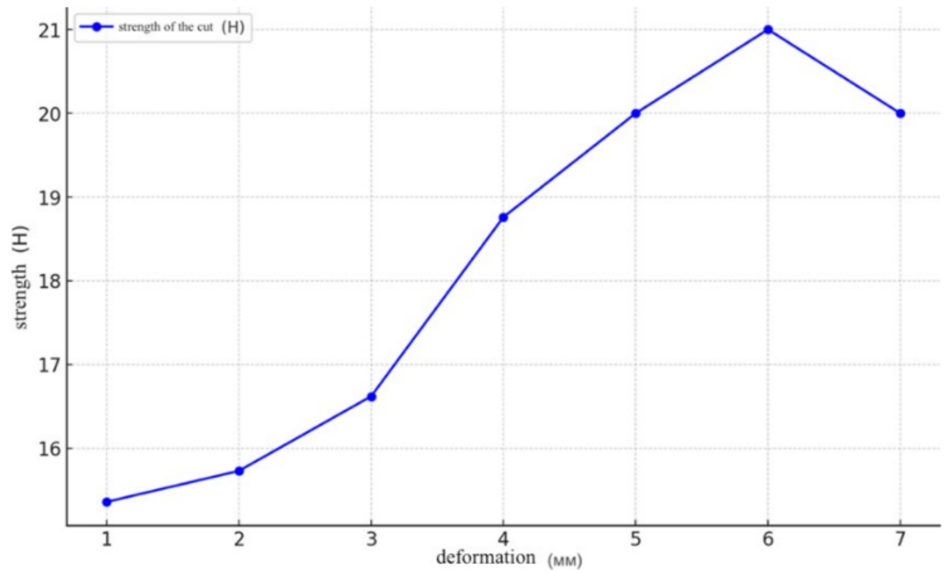

Figure 1 - Shear Force of Chicken Distal Limbs

At the initial stage (1–2 mm), the shear force gradually increases, starting from approximately 16 N. Between 3–5 mm of deformation, a more substantial increase in shear force is observed, reaching 20 N. The maximum shear force (21 N) is recorded at around 6 mm of deformation. Following this, at 7 mm of deformation, the shear force slightly decreases to just above 20 N.

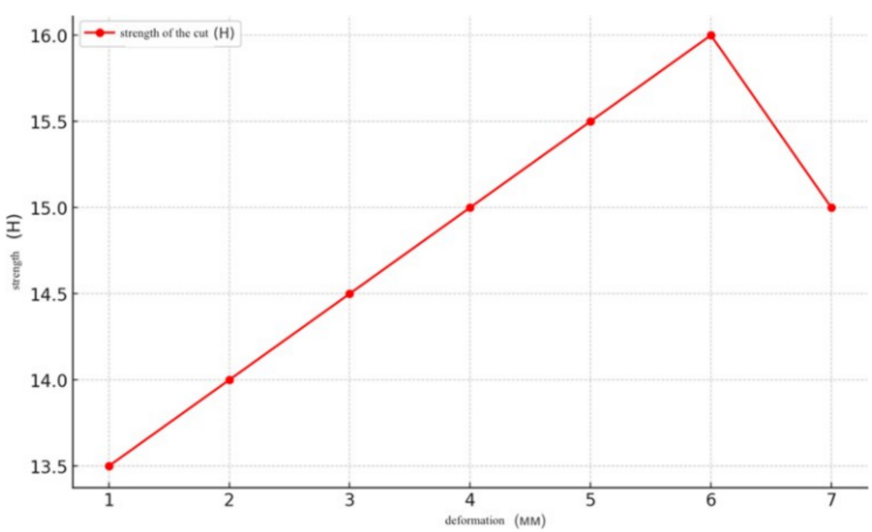

Figure 2 - Shear Force of Chicken Stomachs

At the initial stage (1–2 mm), the shear force of chicken stomachs starts at around 13.5 N and gradually increases. From 3 to 5 mm, a linear increase in shear force is observed, reaching approximately 15.5 N. The maximum shear force is recorded at 6 mm of deformation, measuring around 16 N. Beyond this point, at 7 mm of deformation, the shear force decreases to 15 N.

Based on the obtained data on shear force, deformation, and shear rate, the shear stress and viscosity of the meat raw material were determined (Figure 3).

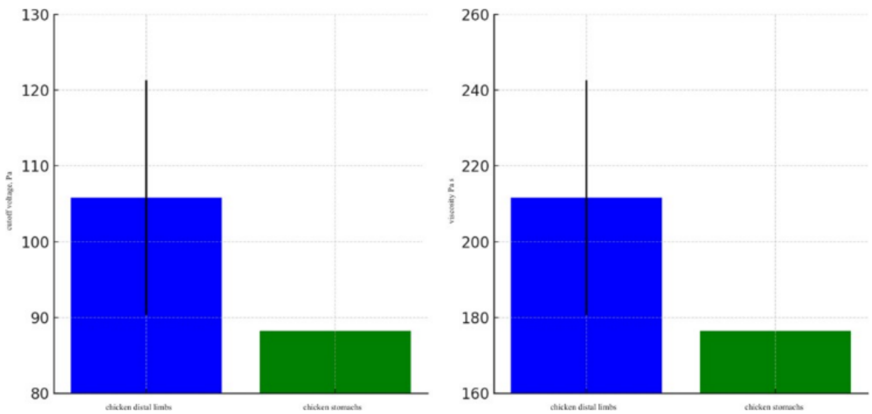

Figure 3 -Shear Stress and Viscosity of Meat Raw Material

The shear stress for chicken distal limbs reaches approximately 110 Pa, indicating high mechanical strength and structural stability of this raw material. The shear stress for chicken stomachs is somewhat lower, around 90 Pa, which also reflects robust structures suitable for further processing. The viscosity of chicken distal limbs is approximately 220 Pa·s, indicating a high capacity for retaining moisture and fats, an essential characteristic for hydrolysate production. The viscosity of chicken stomachs is lower, around 180 Pa·s, which is also an acceptable value for collagen extraction processes.

The study of water-binding capacity (WBC) of chicken limbs and stomachs further allows for an assessment of their potential as collagen sources. Collagen-rich limbs and stomachs demonstrate a high capacity to retain water, which can significantly enhance the texture and stability of hydrolysates (fig.4).

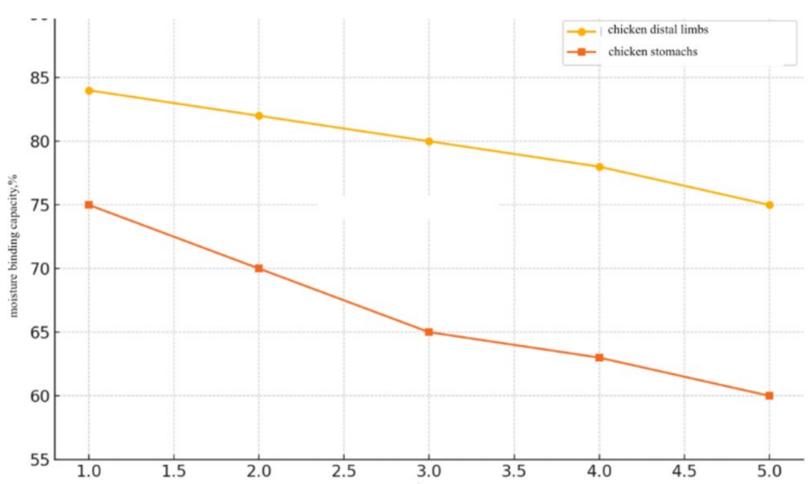

Figure 4 – Changes in Water-Binding Capacity (WBC) of Meat Raw Material Over 5 Days

The water-binding capacity (WBC) of chicken distal limbs (yellow line) starts at around 85% on the first day and gradually decreases to 80% by the fifth day, indicating relatively high moisture retention stability over the study period. The WBC of chicken stomachs (orange line) is initially lower, about 75% on the first day, and continues to decrease to approximately 65% by the fifth day.

For successful collagen hydrolysate production, the initial physicochemical properties of the raw material, such as moisture content, water activity, and pH, play a crucial role (Table 1).

Table 1 – Physicochemical Properties of Meat Raw Material

Indicators	Storage, days	Chicken Distal Limbs
Moisture, %	1 days	65,42 ± 0,06
	3 days	59,1 ± 0,11
	6 days	57,6 ± 0,12
	9 days	57,2 ± 0,12
Active Acidity, pH	1 days	6,17 ± 0,12
	3 days	6,19 ± 0,09
	6 days	6,25 ± 0,05
	9 days	6,24 ± 0,06
Water Activity aw, c.u.	1 days	0,825± 0,003
	3 days	0,827± 0,002
	6 days	0,824± 0,000
	9 days	0,819± 0,002

Chicken distal limbs and stomachs exhibit similar moisture values at each stage of storage. On the first day, the moisture content of chicken limbs is 65.42%, while that of chicken stomachs is 67.34%. By the sixth day, these values decrease to 57.6% and 59.3%, respectively. Despite the overall reduction in moisture, both types of raw materials maintain sufficiently high levels, which is crucial for hydrolysis, as hydrolysates require a certain moisture level for effective protein extraction. The slightly higher moisture content in chicken stomachs potentially makes them more efficient for hydrolysate production, particularly in scenarios where maximum moisture retention is essential.

A detailed analysis of the chemical composition is crucial to assess the suitability of various raw materials for collagen hydrolysate production. The chemical composition determines key parameters such as protein, collagen, fat, and moisture content, which directly affect the hydrolysis efficiency and the quality of the final product. Let us consider the chemical composition of chicken distal limbs and stomachs to evaluate their potential for further processing and use in protein hydrolysate production (Table 2).

Table 2 – Chemical Composition of Meat Raw Material

Indicators	Chicken Distal Limbs, %	Chicken Stomachs, %
Fat	14,6	2,1
Protein	21,1	21,4
Moisture	2,3	2,9
Collagen	11,3	7,5
BEFFE	17,9	14,7

Chicken distal limbs contain 14.6% fat, which is significantly higher than the 2.1% fat content found in chicken stomachs. The high fat content in distal limbs may require additional processing for fat removal prior to hydrolysis; however, the extracted fat can also be utilized in other production processes, such as the development of bioactive components. Stomachs, with their lower fat content, require less intensive preparation, simplifying the hydrolysis process.

Conclusion. The results of the study confirm the high suitability of chicken distal limbs and stomachs for processing into collagen protein hydrolysates. The chemical composition of

these raw materials highlights key components that make them promising for applications across various industries. Specifically, chicken distal limbs contain 11.3% collagen, significantly higher than the 7.5% in chicken stomachs, indicating their substantial value for collagen-containing products. Additionally, distal limbs exhibit a higher BEFFE (17.9% versus 14.7% in stomachs), suggesting better protein extractability, which is beneficial for hydrolysis processes. Chicken stomachs, despite having a lower collagen content, offer notable advantages, such as low fat content (2.1% compared to 14.6% in limbs) and high protein concentration (21.4%), making them ideal for processes that require minimal fat. This simplifies the pre-treatment of raw materials before hydrolysis, allowing efficient use in protein product manufacturing. Thus, processing chicken distal limbs and stomachs for collagen hydrolysate production represents an economically viable and environmentally sustainable approach to utilizing poultry slaughter by- products.

Financing. *This research is funded by the Ministry of Agriculture of the Republic of Kazakhstan (BR24892775)*

References

1. Luchkin, A., Lukasheva, O., Novikova, N., Zyatkova, A., & Yarotskaya, E. (2021). Feasibility study of the influence of the diet on the quality characteristics of poultry production. IOP Conference Series: Earth and Environmental Science, 640. DOI 10.1088/1755-1315/640/3/032041.

2. Pica-Ciamarra, U., & Otte, J. (2010). Poultry, food security and poverty in India: looking beyond the farm-gate. World' s Poultry Science Journal, 66, 309 - 320. DOI 10.1017/S0043933910000358.

3.Akinola, L., & Essien, A. (2011). Relevance of rural poultry production in developing countries with special reference to Africa. World' s Poultry Science Journal, 67, 697 - 705. DOI 10.1017/S0043933911000778.

4.Mead G. C. Poultry meat processing and quality. – Cambridge: Woodhead Publishing Limited, 2004. – 400 p. ISBN I 85573 727 2

5.Baker, R., & Passmore, D.Role of Poultry & Egg Production in the Economy of the United States.//SSRN Electronic Journal.-2010.- DOI 10.2139/SSRN.1581500.

6.Pankova, S., & Katerinich, O. Efficiency of using the new domestic meat-egg hybrid for the production of food eggs in household farms// Agricultural Science and Practice.-2017.- Vol. 4(2).- P.47-51. DOI 10.15407/agrisp4.02.047.

7.Efremova, A. (2018). Role of Poultry Industry in public food supply// Economic Sciences for Agribusiness and Rural Economy.- 2018.-Vol. 2.- S. 29-36. DOI 10.22630/esare.2018.2.2.

8.Sonaiya, E. (2007). Family poultry, food security and the impact of HPAI. //World' s Poultry Science Journal.- 2207.- Vol.63(1).-P. 132 - 138. DOI 10.1017/S0043933907001353.

9.Gunnarsson, S., Segerkvist, K., Göransson, L., Hansson, H., & Sonesson, U. (2020). Systematic Mapping of Research on Farm-Level Sustainability in Egg and Chicken Meat Production// Sustainability.-2020-Vol. 12(7), 3033. DOI 10.3390/su12073033.

10.Mottet, A., & Tempio, G. (2017). Global poultry production: current state and future outlook and challenges// World' s Poultry Science Journal/-Vol. 73,.-P.245 - 256. DOI 10.1017/S0043933917000071.

11. Karkach, P., Mashkin, Y., & Fesenko, V. (2023). Environmental problems of industrial and organic poultry farming// Tehnologìâ virobnictva ì pererobki produktìv tvarinnictva.-2023.-Vol.1.- P.145-158. DOI 10.33245/2310-9289-2023-178-1-145-158. [in Ukrainian]

12. Laca, A., Laca, A., & Díaz, M. (2021). Environmental impact of poultry farming and egg production// Environmental Impact of Agro-Food Industry and Food Consumption.-2021.-P.81-100. DOI 10.1016/B978-0-12-821363-6.00010-2.

13.Oficial' nyj informacionnyj resurs Prem' er-ministra Respubliki Kazahstan URL: https://primeminister.kz [in Russian]

Information about the authors

Tultabayeva T. - Doctor of Technical Sciences, Associate Professor, Kazakh Agrotechnical Research University named after S.Seifullin, Astana, Kazakhstan, e-mail: tultabayeva@inbox.ru;

Makangali K. – PhD, Kazakh Agrotechnical Research University named after S.Seifullin, Astana, Kazakhstan, e-mail: kmakangali@mail.ru;

Tokysheva G. - PhD, Kazakh Agrotechnical Research University named after S.Seifullin, Astana, Kazakhstan, e-mail: tokisheva_g@mail.ru;

Shoman A. - PhD, Kazakh Agrotechnical Research University named after S.Seifullin, Astana, Kazakhstan, e-mail: shoman_aruzhan@mail.ru;

Aiken D. - Master of Technical Sciences, Kazakh Agrotechnical Research University named after S.Seifullin, Astana, Kazakhstan, e-mail: didi_dom@mail.ru.

Сведения об авторах

Тултабаева Т.Ч. – д.т.н., доцент, Казахский агротехнический исследовательский университет им.С.Сейфуллина, Астана, Казахстан, e-mail: tultabayeva@inbox.ru;

Макангали К.К. - PhD, Казахский агротехнический исследовательский университет им.С.Сейфуллина, Астана, Казахстан, e-mail: kmakangali@mail.ru;

Токышева Г.М. - PhD, Казахский агротехнический исследовательский университет им.С.Сейфуллина, Астана, Казахстан, e-mail: tokisheva_g@mail.ru;

Шоман А.Е. - PhD, Казахский агротехнический исследовательский университет им. С.Сейфуллина, Астана, Казахстан, e-mail: shoman_aruzhan@mail.ru;

Айкен Д.К. – м.т.н., Казахский агротехнический исследовательский университет им.С.Сейфуллина, Астана, Казахстан, e-mail: didi_dom@mail.ru.