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Analysis of heavy metals content in domestic and imported poultry meat

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Abstract

Background and Aim. Heavy metal contamination of the environment and food has attracted intense public attention as it poses a serious threat to the ecological system and human health. Heavy metals are chemical elements that have a toxic effect on the human body. The expansion of various industries has led to a significant increase in levels of these components within envi-ronment.

Materials and Methods. Current work represents diagnostics and comparison of the content of heavy metals in poultry meat of domestic production and imported origin studied in 2023 using inductively coupled plasma mass spectrometry (ICP-MS).

Results. Large concentrations of arsenic and lead were found in the samples, not exceeding the maximum permissible concentrations, while the content of mercury and cadmium was at trace levels. The obtained data allows to assess the level of heavy metal contamination and compare the safety of poultry meat produced in the Republic of Kazakhstan and abroad.

Conclusion. A clear understanding of the ways and mechanisms by which heavy metals pose a risk to human health when consuming contaminated food products makes it possible to adopt appropriate strategies for managing and mitigating their negative effects. In addition, development of hand-held portable devices is needed for timely on-site diagnostics of HMs to ensure quality of meat products is sufficient for human consumption.

Key words: food monitoring; heavy metals; ICP-MS; poultry meat.

Introduction

Ensuring the safety and quality of food products is an important task of the state policy of healthy nutrition and acts as a key link in preserving the food independence of Kazakhstan. A person must consume the elements necessary for the body, but along with this, a large number of potentially dangerous chemicals can be consumed [1]. This is due to the fact that environmental pollution is aggravated by the industrial revolution and human anthropological activity [2]. Thus, toxic elements are found in 90% of the studied food products [3].

Heavy metals (HMs) are a group of pollutants that have recently become widespread, be-longing to the groups of trace and ultratrace elements according to the biological classification [4, 5]. In the environment, HMs manifest themselves as toxicants and ecotoxicants, where the toxicants are elements that have a harmful effect on an organism or group of organisms, whereas the ecotoxicants are elements or compounds that negatively affect ecosystem as a whole [6]. Toxic metals such as cadmium (Cd), arsenic (As), mercury (Hg) and lead (Pb) are among the most dangerous for the environment, human and animal health [7]. Generally, the main sources of HM-based environmental pollution are heavy industry, motor vehicles, boiler houses and incinerators, as well as production and use of agricultural fertilizers and pesticides [8, 9]. HM compounds enter the body mainly through the gastrointestinal tract with concentrated foods and water, to a lesser extent through the respiratory organs [10].

Today, great attention is paid worldwide to the protection of the habitat and the internal environment from the increasing action of chemical substances (in particular, HMs and soluble forms of their toxic compounds) of an anthropogenic and original nature [11]. In this regard, monitoring of food products in Kazakhstan is the most important state task. The monitoring is based on the content control of pollutants, including HMs in food, which are regulated according to sanitary and hygienic standards. One of the main organizations that are responsible for food monitoring in Kazakhstan is the Republican State Enterprise on the Right of Economic Use "National Reference Center for Veterinary Medicine" of the Committee for Veterinary Control and Supervision of the Ministry of Agriculture of the Republic of Kazakhstan (NRCV).

The objects of monitoring are raw materials of animal origin, such as meat, milk, fish, honey and chicken eggs. Among them, one of the most important food products is chicken meat (poultry meat), since it is a source of animal protein at an affordable price [12]. The era of globalization requires competitive products. Current domestic poultry meat producers must ensure not only accessibility, but also products that are safe to eat. The safety of poultry meat starts from the farm, from the processing process to the moment of consumption.

Since its introduction in the 1980s, ICP-MS has become, perhaps, the most versatile method for detecting specific elements. Unlike other popular methods of mass spectrometric ionization, ICP-MS uses a high-temperature plasma discharge as a source of predominantly single positively charged ions. As a result, ICP-MS has become a powerful and reliable method for detecting most of the elements present in the periodic table [13]. In ICP-MS, noble gases such as argon are mainly used as plasma gas, in which effective evaporation, dissociation or atomization, excitation and final ionization of the analyzed components of the sample occur. In addition, this high-temperature process leads to complete fragmentation of each molecule of the sample, leaving only their detectable atomic components, namely metals, metalloids or heteroatoms [14].

The purpose of this work was to detect and compare the level of contamination of poultry meat of domestic production and imported origin with such HMs as arsenic, cadmium, mercury and lead. As a result, no HM was found above the permissible level, however, it is worth mentioning that in the samples from one of the studied farms, the «Izhevsky PC» in the Akmola region, a sufficiently high number of HMs was detected compared with others. As this was the first study in Kazakhstan to conduct a comparative analysis of the heavy metal content in poultry meat from domestic and imported sources, this research provides valuable data.

Materials and Methods

Samples of poultry meat, namely broiler chickens, were taken as test objects. A total of 41 samples were examined including 25 domestic production and 16 imported origins .The samples were collected by the Territorial Inspections of the Committee for Veterinary Control and Supervision of the Ministry of Agriculture of the Republic of Kazakhstan in accordance with the Rules for sampling of transported objects and biological material approved by the Order of the Minister of Agriculture of the Republic of Kazakhstan dated April 30, 2015, No. 7-1/393 [15] and deliv-ered to NRCV. The prefrozen samples were transported in thermal containers with gel and liquid refrigerants.The samples were collected from the following enterprises of the Republic of Ka-zakhstan: LLP «Poultry-Agro» (Kostanay region) – 1 sample; LLP «Turkey PVL» (Pavlodar re-gion) – 1 sample; LLP «PTF Yessil Poultry Farm» (North Kazakhstan region) – 1 sample; LLP «Zapad K» (West Kazakhstan region) – 1 sample; Astana markets – 2 samples; LLP «Aknar PF» (Karaganda region) – 1 sample; LLP «Makinskaya Poultry Farm» (Akmola region) – 9 samples; LLP «Izhevskiy» (Akmola region) – 2 samples; LLP «CAPITAL PROJECTS LTD» (Akmola region) – 7 samples (Fig. 1). Number of samples by importing countries: United States of America – 6, Russian Federation – 4, Republic of Belarus – 3 and Ukraine – 3 samples.

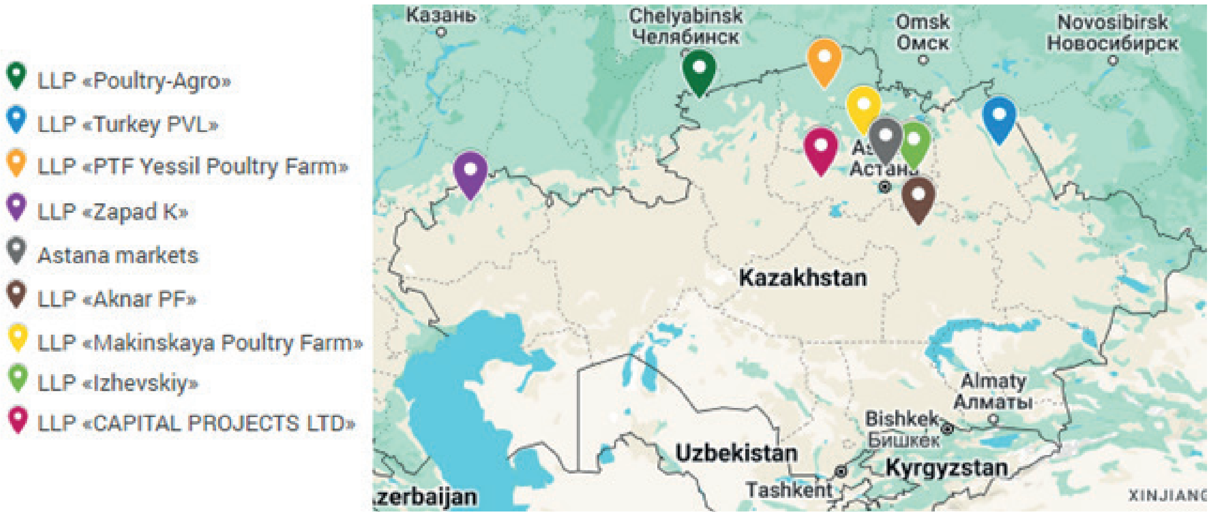

Figure 1 – Sampling sites of the studied poultry meat samples on the map of the Republic of Kazakhstan (Google Maps)

Sample preparation was carried out by the method of decomposition under pressure. This physico-chemical method is designed for the detection of trace elements in food products by mineralizing samples using a microwave system. When preparing the samples, the requirements of the EN 13805-2012 standard were followed [16]. The Multiwave GO Plus (Anton Paar GmbH, Germany) microwave decomposition system was used for decomposition.

Arsenic, cadmium, mercury and lead were included in the range of defined HMs. The studies were performed on the basis of a quadrupole mass spectrometer with inductively coupled argon plasma ICP MS Agilent Technologies 7500 (Agilent Technologies, USA), with an operating mass range from 5 to 240 am. The analysis was carried out in accordance with the requirements of the standard ST RK EN 15763-2017 [17]. The data were analyzed using the MassHunter quantitative calculation software, which supports efficient data collection and management of the mass spectrum library.

Calibration standards were prepared with a multi-element solution IV-ICPMS-71A containing arsenic, lead and cadmium, as well as a single-element solution of mercury MSHGN-10PPM. These standards of the Inorganic Ventures company (USA) are produced in accordance with ISO 17034, ISO 17025 and are traceable in NIST (National Institute of Standards and Technology, USA). Solutions of various concentrations (5 µg/L, 10 µg/L, 20 µg/L, 50 µg/L and 100 µg/L) were used for calibration of ICP-MS, taking into account the linear dynamic range. As well as a blank (control) sample, deionized water with the addition of nitric acid was used, which was subjected to the same sample preparation procedure described above. The error bars represent the standard deviation obtained using the automatic function of three-fold repetition of measurements. Moreover, the Student's t-test for independent populations was used for determination of statistical significance of differences in the average values of HM content.

All chemical reagents and materials used in this study were of high analytical purity. In the laboratory, the accuracy and reliability of the results were achieved through participation in interlaboratory comparison analyses, including with foreign qualification verification providers such as FAPAS, England. All studies were conducted in the laboratory "Analysis of food products" of the NRCV, which is accredited according to GOST ISO IEC 17025-2019 for the detection of HMs by the ICP MS method.

Results

Data on the content of HMs in poultry meat samples studied in 2023 are shown in Figure 2. The maximum permissible levels regulated by the Customs Union are for arsenic 0.1 mg/kg (100 µg/kg), cadmium 0.05 mg/kg (50 µg/kg), mercury 0.03 mg/kg (30 µg/kg) and 0.5 mg/kg (500 µg/kg) of lead were not exceeded in the studied poultry meat samples [18].

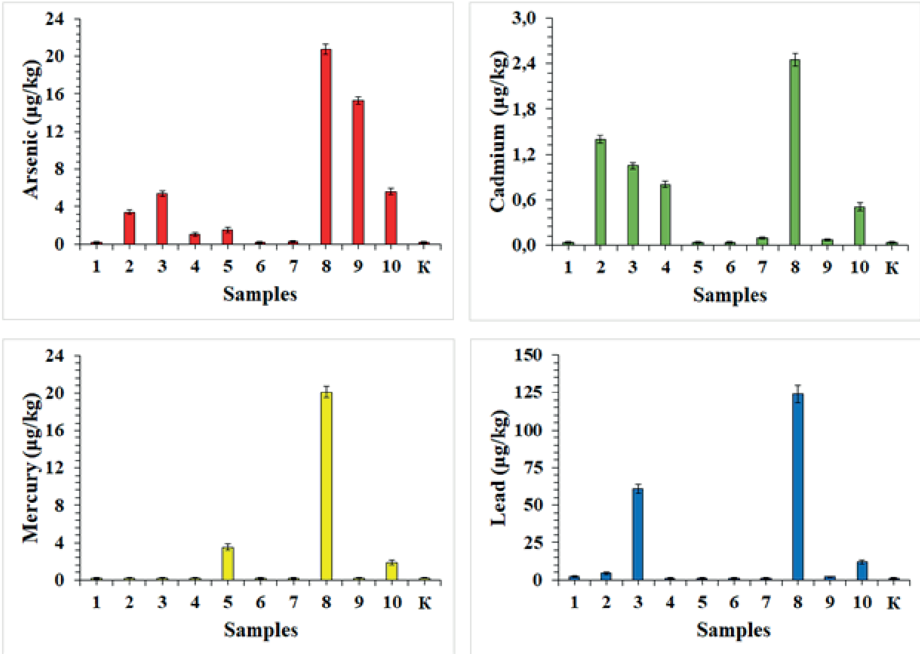

Figure 2 – Average content of heavy metals (µg/kg) in poultry meat studied in 2023: 1-LLP «Poultry-Agro»; 2 - LLP «Turkey PVL»; 3 - LLP «PTF Yessil Poultry Farm»; 4 - LLP «Zapad K»; 5 - Astana markets; 6 - LLP «Aknar PF»; 7 - LLP «Makinskaya Poul-try Farm»; 8 - LLP «Izhevskiy»; 9 - LLP «CAPITAL PROJECTS LTD»; 10 - Imported poultry meat. As well as a blank (control) sample, deionized water with the addition of nitric acid was used, which was subjected to the same sample preparation procedure de-scribed above – K. The error bars are the standard deviation obtained using the automat-ic three-fold measurement repetition function

According to Figure 2, the average arsenic content in poultry meat ranged from 0.26 µg/kg to 20.7 µg/kg. The lowest concentration of arsenic was found in poultry meat produced by LLP «Makinskaya Poultry Farm», while the highest amount was detected in samples from LLP «Izhevskiy». In contrast, no residual amount of arsenic was detected in poultry meat produced by LLP «Poultry-Agro» and LLP «Aknar PF». The average arsenic content for all samples of poultry meat produced in Kazakhstan was - 5.28 µg/kg and in imported - 5.59 µg/kg, which in turn is much lower than the permissible amount of arsenic (Fig. 3). These indicators are extremely im-portant because arsenic has genotoxicity that causes cognitive and reproductive dysfunction. The toxic effect of arsenic can lead to bladder and lung cancer [19].

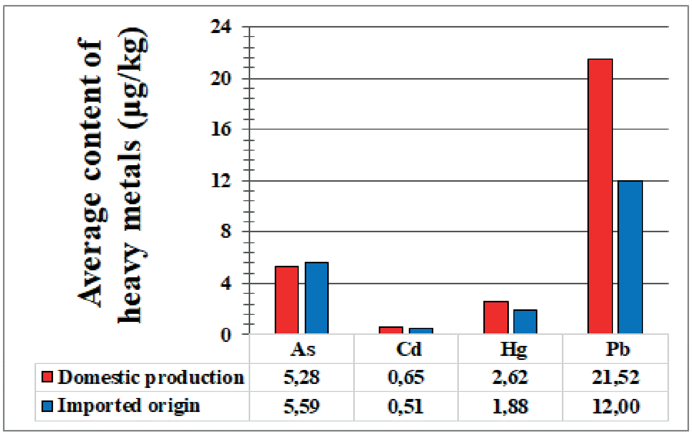

Figure 3 – Average content of arsenic, cadmium, mercury and lead for poultry meat samples of domestic producers and imported origin

Cadmium, a heavy metal vapor and a compound of which are toxic to the human body. Cadmium poisoning leads to damage to the kidneys, central nervous system and immune system. It causes damage to bones and the reproductive system [20].

The following minimum and maximum values of cadmium were found in the studied poultry meat samples: 0.06 μg/kg in poultry meat produced by LLP «CAPITAL PROJECTS LTD» and 2.45 μg/kg by LLP «Izhevskiy». Cadmium concentrations were not detected in the samples obtained at the markets of Astana, LLP «Poultry-Agro» and LLP «Aknar PF» (Figure 2). It was established that the average concentration of cadmium in domestic (0.65 μg/kg) and imported (0.51 μg/kg) poultry is 100 times less than the permissible level.

Mercury is a neurotoxin that is a global pollutant, and its organic form, methylmercury, is associated with neurocognitive changes in human fetuses and cardiovascular diseases in adults [20]. As a result of the conducted research, mercury was detected only in poultry meat selected in the markets of Astana – 3.48 μg/kg, LLP «Izhevskiy» – 20.0 μg/kg and in imported products – 1.88 μg/kg (Figure 2). The detected mercury value for imported and domestic poultry meat is 1.88 μg/kg and 2.62 μg/kg, respectively (Figure 3).

An increased concentration of lead in the body affects behavior, cognitive functions, post-natal growth, delays puberty and reduces hearing in infants and children. In adults, lead causes problems of the cardiovascular, central nervous system, kidneys and fertility. During pregnancy, lead can inhibit fetal growth at an early stage [22].

A high concentration (123.8 μg/kg) of lead was detected in poultry meat produced by LLP «Izhevskiy», while the lowest concentration (0.13 μg/kg) was diagnosed in LLP «Makinskaya Poultry Farm». Notably, no lead was detected in the samples of LLP «Zapad K» and LLP «Aknar PF» (Figure 2). The average lead content in domestic poultry turned out to be much higher than in the imported ones (Figure 3).

In some of the testing samples, there was quite high concentration of lead, arsenic and mer-cury. This could be due to the content of HMs in feed, feed additives [23], water [24] and bird droppings [25]. In addition, birds can be treated with antiparasitic baths, sprayers or aerosol generators using pistils, which in turn contain HMs [26]. The cadmium content in poultry meat samples of domestic production and imported origin is at a trace level.

Overall, in poultry meat of domestic production, the lead content was higher by 44.2%, cadmium by 21.5%, mercury by 28.2% than in imported ones, while the arsenic content was higher by 5.5% in the imported products.

To determine the statistical significance of differences in the average values of HM content in domestic and imported poultry meat, Student's t-test for independent populations was used (Table 1).

Table 1 - Calculated data using Student’s t-test

Data	Comparable populations	As	Cd	Hg	Pb
Number of measurements (n)	Domestic	9	9	9	9
	Import	16	16	16	16
Average value (M)	Domestic	5.28	0.65	2.62	21.51
	Import	5.59	0.51	1.88	12
Average error of the arithmetic mean (m)	Domestic	2.66	0.3	2.34	15.24
	Import	1.63	0.22	1.62	9.94
Number of degrees of freedom (f)		23	23	23	23
Level of significance (p)		0.05	0.05	0.05	0.05
Critical value of Student's t-test		2.069	2.069	2.069	2.069
The meaning of the Student's t-test		0.10	0.38	0.26	0.52

We compared the obtained values of the Student's t-test with the critical value of the Stu-dent's t-test, which, with the number of degrees of freedom (f) equal to 23 and the significance level (p) = 0,05, is 2,069. The obtained values were greater than the critical value, according to which we concluded that the differences between the content of heavy metals in domestic and imported poultry meat were statistically insignificant.

According to the results of this study, it was determined that the poultry meat of imported origin and domestic production meet the hygienic requirements of food safety in terms of HM content and are safe in accordance with regulations. The risk assessment based on the obtained data did not reveal any harm to the health of the population.

However, due to the ability of HMs to accumulate in the body, it is worth considering that, having accumulated and exceeded the established norms, HMs can cause great harm to human health [27]. Regular consumption of products, even with a low content of HMs, leads to disruption of the body.

Discussion and Conclusion

Due to the obtained data and their statistical analysis in this study, it can be concluded that the difference in the HM content in poultry meat samples of domestic and imported origin is not significant. We assume that this could be due to approximately the same conditions of maintenance and growing technology, identical methods of treatment and processing, as well as a similar diet of broiler chickens in poultry farms of all countries. Notably, no heavy metal exceeding standards was detected in both domestic and imported meat samples. However, even small amounts of HMs can potentially affect human health.

In fact, environmental pollution, food safety and human health are inextricably linked. Concentrations of HMs in the environment have been significantly increased in recent decades due to global industrial progress. A reliable diagnostics, accurate analysis and assessment of potential risks caused by HMs allow an application of timely management strategies for reducing and/or preventing the HM contaminations. Moreover, development of portable devices is needed for on-site diagnostics of HMs for constant timely tests provided and regulated by government to ensure highquality food products for daily consumption.

Authors' Contributions

M.B., O.O. and K.D. conceived and planned the research. O.O., V.K. and A.K. carried out the experiments. A.K. contributed to sample preparation. O.O., V.K. and A.O. contributed to the interpretation of the results. O.O. took the lead in writing the manuscript. M.B. and K.D. corrected the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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