Results of comparative research methods for arsenic content in meat samples of broiler chickens

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Abstract. The development of effective algorithms for optimizing the laboratory equipment base is one of the urgent tasks. Arsenic is classified as a toxicant of the highest hazard group; it is a highly toxic cumulative poison with a broad spectrum of action. The paper considers an assessment of the method for researching the content of arsenic in meat and meat products. The results of investigations (by the methods of photoelectric colorimetry and stripping voltammetry) on the operational control of the error using the method of additions and the assessment of precision were recognized as satisfactory. Comparative analysis of two methods of photoelectric colorimetry and stripping voltammetry in assessing the content of arsenic in samples of broiler chicken meat showed their relevance in the development of laboratory practice. 45.2% over other ranges. The least registered sample results (1.1%) with the range of obtained data - 0.1-1.0 mg/kg.

1. Introduction
The issues of the influence of nutrition on human health are discussed by many researchers [1-5], the level of exposure to xenobiotics entering the human body with food is constantly analyzed [6-9]. Research of food products and food raw materials for compliance with modern international quality standards is a component that determines the competitiveness of many laboratories [10-13]. The development of effective algorithms for optimizing the laboratory equipment base is one of the urgent tasks [12-18]. An important task is to ensure control of the quantitative content of heavy metals (including arsenic) [19-26].

This paper considers such a toxic element as arsenic, which is mandatory for control in meat and meat products, in accordance with the requirements of the Technical Regulations of the Customs Union 021/2011 (TR CU 021) "On food safety", as amended on August 8, 2019 (figure 1).
Figure 1. Permissible levels of arsenic in meat and meat products according to the requirements of technical regulations, mg/kg, not more.

Arsenic is classified as a toxicant of the highest hazard group; it is a highly toxic cumulative poison with a broad spectrum of action. Advantages and disadvantages of voltammetric methods of product testing is shown in figures 2 and 3.

Figure 2. Advantages of the method.

Figure 3. Disadvantages of the method.
The disadvantages and advantages of photoelectric colorimetry of products are shown in figures 4 and 5.

**Figure 4.** Advantages of the method.

**Figure 5.** Disadvantages of the method.

2. Material and Methods

Determination of arsenic (standards and laboratory equipment used are shown in figure 6.

**Figure 6.** Standards and applied laboratory equipment.

The object of research is samples of poultry meat (broiler chickens). Equipment for research of cadmium content in food raw materials and food products is shown in figure 7.
TEST LABORATORY EQUIPMENT

Voltammetric analyzer "Pan-arsenic"
Photocolorimeter "KFK-2 MP"

Figure 7. Research instrument base.

The normative base of standards for the determination of arsenic in these product studies is presented in figures 8 and 9.

Figure 8. Photoelectric colorimetry of food and food raw materials.

Figure 9. Stripping voltammetry on the analyzer "Pan-arsenic".

The main document of the research procedure is the test facility quality manual.

The control by the method of additions during the implementation of various methods in this work was carried out according to the approved research scheme.

During the operational control of the analysis procedure using the control procedure to control the error using the method of additions, the control means were working samples of a stable composition and the same samples with a known addition of arsenic.

Under the conditions of in-laboratory precision, the analysis of samples with and without added arsenic was carried out.
3. Results and discussion
In accordance with the requirements of the interstate standard GOST R ISO 5725-6, the acceptability of the results of determining arsenic in products was assessed. The critical range factor \( f(n) \) for the five results is 3.9. Repeatability standard deviation \( S_r \) for each measurement method:

- For "KFK-2MP": \( (CR_{0.95}(5), \%) = f(5) \times S_r(As) = 3.9 \times 25 = 97.5 \% \)
- For "Pan-arsenic": \( (CR_{0.95}(5), \%) = f(5) \times S_r(As) = 3.9 \times 17 = 66.3 \% \)

The absolute value of the critical range \( CR_{0.95}(5) \) is calculated by the formula:

\[
CR_{0.95}(5) = 0.01 \times (CR_{0.95}(5), \%) \times X_{avr}(5)
\]

If the range between the maximum and minimum values of five analysis results \( (X_{max} - X_{min}) \) is equal to or less than the absolute value of the critical range \( CR_{0.95}(5) \), then the results of the analysis performed under conditions of repeatability and intermediate precision are considered satisfactory.

The research results are presented in table 1.

### Table 1. Results of studies of poultry meat for arsenic content.

| №   | Pan-arsenic | KFK-2MP | Pan-arsenic | KFK-2MP | Pan-arsenic | KFK-2MP |
|-----|-------------|---------|-------------|---------|-------------|---------|
|     | Cд=0.1 stage sample preparation |        | Cд=0.1 measurement stage |        |
| 1   | 0.041       | 0.036   | 0.126       | 0.118   | 0.129       | 0.131   |
| 2   | 0.037       | 0.034   | 0.133       | 0.123   | 0.136       | 0.128   |
| 3   | 0.039       | 0.036   | 0.131       | 0.114   | 0.146       | 0.128   |
| 4   | 0.043       | 0.032   | 0.112       | 0.103   | 0.135       | 0.127   |
| 5   | 0.045       | 0.029   | 0.119       | 0.106   | 0.126       | 0.135   |
| X\text{avr} | 0.041 | 0.0334 | 0.1242 | 0.1128 | 0.1344 | 0.1298 |

Assessing the precision of results \( (X_{max} - X_{min}) \leq CR_{0.95}(5) \)

\[
0.008<0.027 \quad 0.007<0.033 \quad 0.021<0.082 \quad 0.02<0.11 \quad 0.02<0.09 \quad 0.008<0.13
\]

3.1. Monitoring the stability of analysis results using the additive method
Operational control of the analysis procedure was carried out by the contractor by comparing the result of a separate control procedure Kk with the calculated control standard K. Operational control of the procedure for testing products for arsenic content provides for the following operations are shown in figure 10.

The means of control were working samples of the stable composition of arsenic and the same samples with a known addition of the arsenic determined by us during the operational control of the analysis procedure using the control procedure to assess the error using the addition method (according to the approved procedure).

In accordance with the methods of analysis, the results of control measurements of the concentration of arsenic in the averaged working sample \( - X_{(n)} \) and in the averaged working sample with a known addition of arsenic \( - X_{(n)+0} \).

The analysis procedure is considered satisfactory if the following conditions are met:

\[
| K_k | \leq K
\]
The results of the operational control of the analysis procedure using the control procedure to control the error using the addition method are summarized in tables 2 and 3.

**Table 2.** Results of investigations of samples for arsenic content using the addition method (addition of arsenic at the stage of sample preparation).

| KFK-2MP | Pan-arsenic |
|---------|-------------|
| Kk      | K           | Kk | K       |
| -0.142  | 0.1858      | -0.1 | 0.24723 |
| -0.0104 | 0.01865     | -0.0074 | 0.01372 |
| -0.0044 | 0.00538     | -0.0042 | 0.00595 |
| -0.0206 | 0.0247      | -0.0168 | 0.01868 |

The condition $|K_{k}| \leq K$ is fulfilled for all measurement results.

The evaluation of the precision of the results obtained by different methods is carried out by calculating the relative error, which reflects the measurement accuracy, and comparing it with the standard deviation of the reproducibility of the result when implementing different research methods.

The analysis procedure is considered satisfactory if the condition: $\sigma \leq \sigma_{R}$.

**Table 3.** Results of studies of samples for arsenic content using the method of additions (additive at the stage of measurements).

| KFK-2MP | Pan-arsenic |
|---------|-------------|
| Kk      | K           | Kk | K       |
| -0.086  | 0.257219    | -0.008 | 0.3411 |
| -0.0046 | 0.019748    | -0.0028 | 0.01431 |
| -0.0004 | 0.006216    | -0.003 | 0.00611 |
| -0.0036 | 0.028146    | -0.0066 | 0.02007 |

Table 4 shows the study of evaluating the precision of product test results for arsenic content, obtained by photoelectric colorimetry and voltammetry, by calculating the relative error and comparing it with the standard deviation of the reproducibility of the results.
Also, the stability of the results of testing products for arsenic content, obtained by photoelectric colorimetry and voltammetry, was monitored, and the operational error control was carried out using the additive method.

Operational control of the analysis procedure was carried out by comparing the result of a separate control procedure $K_k$ with the calculated control standard $K$.

The values of $X_{cp(n)}$ and $X_{cp(n)+\vartheta}$ were taken as the average values of the averaged results of five measurements obtained by different methods (calculated by formula 3.10), in samples without an additive and in samples with an additive.

### Table 4. Results of studies of poultry meat for arsenic content.

|                  | Pan-arsenic | KFK-2MP | Pan-arsenic | KFK-2MP | Pan-arsenic | KFK-2MP |
|------------------|-------------|---------|-------------|---------|-------------|---------|
|                  |             |         | additive at the stage of sample preparation $c=0.1$ |         | additive at measurement stage $c=0.1$ |         |
| $X(5)_{avr}$     | 0.041       | 0.0334  | 0.1242      | 0.1128  | 0.1344      | 0.1298  |
| $X_{avr}$        | 0.0372      | 0.0372  | 0.1185      | 0.1185  | 0.1321      | 0.1321  |

**Evaluation of the precision of results obtained by different methods**

|                  | 10.2 % < 22 % | 4.8 % < 22 % | 1.7 % < 22 % |
|------------------|---------------|---------------|---------------|
| $K_k$            | -0.0187       | 0.02295249    | -0.0051       |
| $K$              | 0.02536157    | 0.02536157    | 0.02536157    |

The results of investigations (by the methods of photoelectric colorimetry and stripping voltammetry) on the operational control of the error using the method of additions and the assessment of precision were recognized as satisfactory.

### 3.2. Research results monitoring

We monitored the results of studies on the content of arsenic in poultry meat from January 2019 to October 2020. We assessed the distribution of research results depending on the concentration of arsenic in poultry meat (figure 11).

![Figure 11. Distribution of test results depending on the concentration (mg / kg) of arsenic in chicken meat samples, %](image-url)
The obtained monitoring results indicate that in the range of less than 0.02 mg of arsenic per 1 kg of poultry meat, k prevails (45.2%) over other ranges. The least registered sample results (1.1%) with the range of obtained data - 0.1-1.0 mg/kg.

4. Conclusion
The analysis of the data obtained shows that all the results on the study of the arsenic content in the meat of broiler chickens on the assessment of precision and operational control of the error using the method of additions are satisfactory.
A comparative analysis of two methods of photoelectric colorimetry and stripping voltammetry in assessing the content of arsenic in samples of broiler chicken meat showed their relevance in the context of the development of laboratory practice.

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