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METROLOGICAL ANALYSIS OF NITRATES AND HEAVY METALS IN CARROTS: A COMPARATIVE STUDY OF THE COMPLIANCE OF CARROT SAMPLES FROM DIFFERENT REGIONS WITH STANDARDS (O'Z DST)

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Abstract

This article presents a metrological analysis of nitrate and heavy metal (lead, cadmium, arsenic) content in carrot (Daucus carota L.) samples collected from different geographical regions of Uzbekistan and a comparative assessment of their compliance with the requirements of the national standards (Uz DSt). The relevance of the study is explained by the need to monitor nitrate and heavy metal levels in widely consumed vegetables such as carrots to ensure food safety and protect public health. A total of 60 carrot samples from six different geographical regions (northern, southern, eastern, western, central, and mountainous) were analyzed. Nitrate content was determined by ion chromatography (IC) and molecular absorption spectrophotometry, while heavy metal content was determined by atomic absorption spectrometry (AAS) and inductively coupled plasma mass spectrometry (ICP-MS). Metrological characteristics of the measurement results (accuracy, repeatability, reproducibility, limit of detection) were evaluated. The results were compared with the sanitary-epidemiological norms of the Republic of Uzbekistan and the requirements of Uz DSt 1100:2023. According to the study results, 16.7% of the samples exceeded the maximum permissible levels for nitrates, and 33.3% for heavy metals. The highest nitrate content was found in samples from the southern region (362.4±18.3 mg/kg), while the lowest was found in samples from the mountainous region (128.7±9.6 mg/kg). Among heavy metals, lead and cadmium levels were above the norm in carrots grown near industrial areas.

Keywords: carrot, nitrates, heavy metals, metrological analysis, Uz DSt, food safety, atomic absorption spectrometry, ion chromatography.

Introduction

Carrot (Daucus carota L.) is considered one of the most common and important vegetables in the diet of the republic's population. It is valuable for its carotenoids (especially β-carotene), vitamins (groups A, C, E, K, B), and minerals (potassium, manganese). However, as a result of intensive agricultural activities, carrots can accumulate toxic substances such as nitrates and heavy metals (lead, cadmium, arsenic, mercury). The negative impact of nitrates on the human body is associated with their conversion into nitrites and nitrosamines, which possess carcinogenic properties. Heavy metals can lead to chronic poisoning, impaired kidney and liver function, and nervous system diseases. In this regard, a comparative study of the compliance of carrot samples obtained from different regions with standard requirements is an urgent scientific and practical task.

Literature review

The amount of nitrates in carrots has been extensively studied by various researchers. In a study conducted in Iran, the nitrate content in carrot samples was below the maximum permissible limits in all samples, but samples from some cities were found to have a significantly higher nitrate content than others. In carrot samples from the Iranian city of Mashhad, the nitrate content was recorded at 171.60±98.44 mg/kg. In a study conducted in Poland, the nitrate content of carrots grown in traditional and organic farming was within permissible limits, but cases of exceeding the norms in carrots obtained from local markets were recorded.

Research conducted on heavy metals indicates that zinc (Zn) is the most abundant heavy metal in carrot roots. In a study conducted at copper mines in Peru, the cadmium content in carrot samples reached up to 0.1620 mg/kg of arsenic.

Objects and methods of research

In this study, a total of 60 carrot samples were collected from 6 different geographical regions of the Republic of Uzbekistan (northern - Turtkul district, southern - Termez district, eastern - Fergana district, western - Khiva district, central - Samarkand district, and mountainous - Boysun district). Ten samples were taken from each region (five each during the first and second harvesting seasons).

Ion chromatography (IC) and molecular absorption spectrophotometry (salicylic acid method) were used to determine nitrates. Heavy metals (lead, cadmium) were determined using atomic absorption spectrometry (AAS) in a graphite furnace, while arsenic and mercury were determined using inductively coupled plasma mass spectrometry (ICP-MS).

The metrological characteristics of the measurement results (precision, reproducibility, localization, detection limit, measurement uncertainty) were evaluated in accordance with the requirements of ISO 5725-1:1994 and O'z DSt 8.2:2019. The results obtained were compared with the requirements of the sanitary and epidemiological standards of the Republic of Uzbekistan (SanPiN No. 0287-22) and O'z DSt 1100:2023. The maximum permissible amounts (MPC) for carrots are as follows: nitrates ≤300 mg/kg, lead ≤0.3 mg/kg, cadmium ≤0.03 mg/kg, arsenic ≤0.1 mg/kg, and mercury ≤0.02 mg/kg.

Results and analysis

The highest nitrate content was found in samples from the southern region (Termez), averaging 362.4±18.3 mg/kg (338.9 mg/kg in the first harvest and 385.9 mg/kg in the second harvest), which exceeded the MPC (300 mg/kg) in 7 (70%) out of 10 samples from the southern region. Samples from the northern region (Turtkul) averaged 225.4 ± 13.4 mg/kg. Mountain samples (Baysun) have the lowest value at 128.7±7.2 mg/kg. The amount of nitrates in the second harvest season (autumn) was 8–15% higher in all regions compared to the first harvest (summer). In 10 (16.7%) of 60 samples, the nitrate content exceeded the MPC.

Among heavy metals, excess of the MPC for lead (Pb) and cadmium (Cd) was observed in samples from the southern and eastern regions. In the southern zone, the Pb content was 0.42±0.05 mg/kg (REC: 0.3 mg/kg), while the Cd content was 0.041±0.005 mg/kg (REC: 0.03 mg/kg). In the eastern region, Pb is 0.31±0.03.

According to the results of the metrological analysis, the methods used (IC, AAS, ICP-MS) possess high accuracy and reproducibility (3.8–5.1% relative standard deviation for

reproducibility and 5.2–6.4% for restriction). The advantage of the IC method over the spectrophotometric method is the possibility of detection at low concentrations (from 5 mg/kg).

Discussion

The results obtained show that the content of nitrates and heavy metals in carrots varies significantly depending on the geographical region, fertilizer application intensity, and distance from industrial enterprises. In the samples from the southern region (Termez), the nitrate content exceeding the MPC may be related to the high application of nitrogen fertilizers in this region and the composition of irrigation water. Compared to studies in other countries, the nitrate content in carrots grown in Uzbekistan was slightly higher than in Iranian carrots but lower than in Polish and Russian carrots. In terms of heavy metals, the excess of lead and cadmium above the MPC in the southern and eastern regions is explained by the presence of industrial enterprises and transport routes in these areas. A positive correlation (r=0.68) was established between the content of nitrates and heavy metals.

Conclusion

Based on the conducted research, the following conclusions were drawn:

1. The content of nitrates and heavy metals in carrot samples taken from different geographical regions varies significantly depending on the region. The highest nitrate content was found in the southern region (Termez) at 362.4±18.3 mg/kg, while the lowest was found in the mountainous region (Boysun) at 128.7±7.2 mg/kg.

2. Excess of the MPC (300 mg/kg) for nitrates was noted in 16.7% of samples. Most of the excess samples belong to the southern region.

3. For heavy metals, exceeding the MPC was observed in 33.3% of samples. The highest amounts of lead and cadmium were found in samples from the southern and eastern regions.

4. The analytical methods used (ion chromatography, atomic absorption spectrometry, ICP-MS) possess high metrological characteristics and are recommended for determining nitrates and heavy metals in food products.

5. The results obtained indicate the need to strengthen monitoring of nitrates and heavy metals in carrot-growing regions of the republic, especially in the southern and eastern regions.

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