Effect of food processing method on heavy metals content

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The problem of high content of heavy metals in food has spread broadly over the world. The presented study suggests the minimization of heavy metal content in processed food due to different applied techniques such as the frying, boiling, steaming and sous-vide. Three main food products were chosen for investigation – *Daucus carota subsp. Sativus* (carrot), *Solanum tuberosum* (potato) and *Allium cepa* (onion). The concentration of heavy metals (Zn, Pb, Mn, Cd, Cu) was determined in samples investigated by atomic-absorption spectrometer. The health risk index (HRI) was calculated based on obtained data. In all investigated samples, high concentration of lead was identified among the heavy metals. The highest concentration of zinc, lead and manganese was determined in boiled *Daucus carota subsp. Sativus,* cadmium – in sous - vide *Daucus carota subsp. Sativus,* copper – in steamed *Daucus carota subsp. Sativus.* HRI values of cadmium for *Solanum tuberosum* samples were ranged from 6.8 to 7.1 and for lead are ranged between 3.4 and 4.9.

Keywords: heavy metals; vegetable crops; food processing; atomic absorption spectrometry; health risk index.

Өңдеу әдісінің тамақ өнімдеріндегі ауыр металдардың мөлшеріне әсері

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Азық-түлік өнімдеріндегі ауыр металдардың көп болуы бүкіл әлемде кең таралған мәселе. Ұсынылған зерттеу жұмысы әртүрлі қолданылатын технологиялардың арқасында өңделген тағамдардағы ауыр металдардың мөлшерін азайтуды ұсынады. Олардың арасында қуыру, қайнату, бумен пісіру және су-вид түрлері бар. Зерттеу үшін Daucus carota subsp. *Sativus* (сәбіз), *Solanum tuberosum* (картоп) және *Allium cepa* (пияз) сияқты үш негізгі тамақ өнімдері таңдалды. Зерттелген үлгілердің құрамындағы ауыр металдардың (Zn, Pb, Mn, Cd, Cu) концентрациясы атомдық-абсорбциялық спектрометрдің көмегімен анықталды. Алынған мәліметтер негізінде денсаулыққа қауіп индексі есептелді. Барлық зерттелген үлгілерде қорғасынның концентрациясы жоғары екендігі анықталды. Мырыш, қорғасын және марганецтің ең жоғары концентрациясы қайнатылған *Daucus carota subsp. Sativus*-те, кадмий – су-вид әдісімен дайындалған *Daucus carota subsp. Sativus*-те, мыс – буға пісірілген *Daucus carota subsp. Sativus*-те анықталды. Барлық *Solanum tuberosum* үлгілеріндегі кадмий үшін денсаулыққа қауіп индексі 6,8 және 7,1 аралығында, ал қорғасын үшін 3,4 және 4,9 дейін болды.

Түйін сөздер: ауыр металдар; көкөніс дақылдары; тамақ дайындау; атомдық-абсорбциялық спектрометрия; денсаулыққа қауіп индексі.

Влияние способа обработки пищевых продуктов на содержание тяжелых металлов

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Повышенное содержание тяжелых металлов в продуктах питания является широко распространенной проблемой во всем мире, требующей детального изучения. Настоящее исследование предлагает минимизировать содержание тяжелых металлов в пищевых продуктах за счет метода приготовления, таких как обжаривание, отваривание, приготовление на пару и метод су-вид. Для исследования были выбраны три распространенных пищевых продукта, таких как *Daucus carota subsp. Sativu*s (морковь), *Solanum tuberosum* (картофель) и *Allium cepa* (лук). Концентрация тяжелых металлов (Zn, Pb, Mn, Cd, Cu) в исследуемых образцах была определена атомно-абсорбционной спектрометрией. На основании полученных данных был рассчитан индекс риска здоровью. Во всех исследованных образцах была установлена высокая концентрация свинца. Наибольшая концентрация цинка, свинца и марганца была определена в отварной *Daucus carota subsp. Sativus*, кадмия – в *Daucus carota subsp. Sativus,* приготовленной методом су-вид, меди – в приготовленном на пару *Daucus carota subsp. Sativus*. Значения индекса риска здоровью для кадмия во всех образцах *Solanum tuberosum* варьировались от 6,8 до 7,1, а для свинца – от 3,4 до 4,9.

Ключевые слова: тяжелые металлы; овощные культуры; приготовление продуктов питания; атомно-абсорбционная спектрометрия; индекс риска здоровью.

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1. Introduction

Due to rapid industrialization and urbanization activities, heavy metals (HMs) pollution spread over the globe that leads to environmental problems, as well as health hazards to human being [1]. The presence of HMs in the environment can have a natural or industrial origin. Industry is the main emitter of HMs to the environment [2]. Concentration of heavy metals in different foods depends on the soil composition, water, nutrient balance, and metal permissibility, selectivity, and absorption ability of the species. In addition, direct foliar uptake of heavy metals from the atmosphere could also be possible during plant growth [3]. Heavy metals can accumulate in different plant species and living systems [4]. Through the food chain, heavy metals enter the human body, which leads to negative affect to human health. Information about heavy metals in food products are important for adequate food consumption data [5]. Iron, zinc, copper, chromium, cobalt and manganese are essential elements needed, while lead, cadmium, nickel and mercury are toxic at certain levels [6]. Effect of heavy metals on human health has been shown in several researches. In [7-10], it is reported, that cadmium and arsenic may cause kidney dysfunction, lung cancer and destructive influence on neurological system. Excessive amount of lead in blood causes toxic epidermal necrolysis and serious problems with neurologic and hematologic systems and the gastrointestinal tract [11-13]. High content of copper leads to changes in cellular activity, such as regulation of lipid metabolism, gene expression, neuronal activity, resistance of tumor cells to chemotherapeutic drugs, different abnormal mutations and the temporal and spatial distribution of copper in hepatocytes [14-16]. Special attention is required to consider the effect of heavy metals on the body of children and infants, because of some specific features of growing organisms [17]. Another difficulty about substances containing heavy metals is that they are hard crumbling in human body and slowly get out of human organism. This is the reason why heavy metals are considered as one of the most dangerous pollutants of food industry and their concentrations and influence must be controlled and studied thoroughly in complex with soil pollutions by heavy metals [18-21].

Three commonly used types of food product (*Daucus carota subsp. Sativus* – carrot, *Solanum tuberosum* – potato and *Allium cepa* – onion) were chosen as investigated samples. For determination of effect of food processing method on content of heavy metals in investigated samples, in this research, four most commonly used methods of food processing were chosen: frying, boiling, steaming and sous-vide. For evaluation of health risk index, concentration of heavy metals was determined by atomic-absorption spectrometer.

2. Experiment

2.1 Sample pretreatment

Samples were purchased in local market of Almaty, largest city of Kazakhstan and second in Central Asia. All samples were washed by distilled water.

Investigated samples were processed in four different ways: frying, boiling, steaming and sous-vide. Samples were crushed using ceramic knife. Boiling was performed during 30 min in deep teflon skillet. Frying was performed in the same Teflon skillet without application of oil. Samples were fried until the crust is formed. Steaming was performed during 30 min in stainless steel steam cooker through the porous piece of cloth in order to avoid contact between steel surface and samples. Sous-vide was performed during four hours in vacuum bags at 65°C. After cooking, all samples were cut into small pieces and dried in oven "VULCAN" type A-550 (Ney, USA) at 40°C till the constant mass.

In order to avoid contamination of food by metallic dishes and other tools, only teflon, glass and ceramic tools were used during whole process of sample preparation.

2.2 Determination of heavy metals

All reagents used for analysis were analytical grade and purchased in "LaborPharma", Almaty, Kazakhstan.

The certain mass of sample was placed in 250 mL Kjeldahl flask and fully oxidized by the mix of concentrated sulfuric (chemically pure, Russia) and nitric acids (chemically pure, Russia) in the ratio 1:1 at 180°C. The indicator of ending of oxidizing is the release of nitrogen dioxide gas. The content of the flask was quantitatively transferred into the 25 mL flask through paper filter and diluted by bi-distilled water. The samples were measured by atomic-absorption spectrometer (AA – 6200 Shimadzu, Japan) [22].

2.3 Health risk index

HRI was calculated for each sample by following equation [23]:

$$HRI = DIM/R_f$$

where *DIM* is daily intake of heavy metal mg/person/day and R_f is the oral reference dose, mg kg^{-1} body weight d^{-1}. R_{fd} value for Zn, Pb, Cd, Mn and Cu is 1.5, 0.004, 0.001, 0.033, and 0.04, respectively [24].

The health risk index values greater than 1 for human health were not considered safe [23].

The *DIM* was calculated by following equation [19]:

$$DIM = C_m * C_f * D_{FI} / \text{body weight},$$

where C_m is concentration of heavy metal in sample, mg/kg; C_f is conversion factor, which convert the fresh vegetable weight to dry weight; D_{FI} is daily intake of vegetables/food, kg/d.

According to the food basket of Kazakhstan [25], each citizen of Kazakhstan consumes the following amounts of *Allium cepa* – 0.05 kg d^{-1}, *Daucus carota subsp. sativus* – 0.05 kg d^{-1}, *Solanum tuberosum* – 0.26 kg d^{-1}. Average adult weight for Kazakhstan was considered as 60 kg.

3. Results and Discussion

3.1 Content of heavy metals

Among the heavy metals, the highest concentration was identified for lead in differently processed *Daucus carota subsp. sativus*. The highest concentration of lead was determined in boiled *Daucus carota subsp. Sativus* and equal to 73.8 mg/kg, in comparison to the lowest concentration – sous- vide *Daucus carota subsp. Sativus*, it was 1.3 times higher.

According to the Figure 1, the lowest concentration among the heavy metals was determined for cadmium. In all differently processed *Daucus carota subsp. Sativus* samples the concentration of cadmium ranged from 19 to 22 mg/kg. In case of zinc and copper, the concentration of heavy metals did not change significantly depending on method of processing. For manganese, the highest concentration was determined for boiled *Daucus carota subsp. Sativus,* while in comparison to the lowest concentration was 1.4 times higher.

In investigated samples of *Solanum tuberosum,* the highest concentration of lead was determined in boiled sample according to Figure 2. Among the differently processed samples of *Solanum tuberosum,* the lowest concentration of lead was determined in fried sample, which was 1.4 times lower than in boiled sample. The lowest concentration among the heavy metals was for cadmium in *Solanum tuberosum* samples. The content of cadmium was around 19 mg/kg in all samples of *Solanum tuberosum* and did not depend from processing method. For copper, manganese and zinc, it can be stated from Figure 2, that concentration was fluctuated, however insignificantly changed depending on method of processing.

In case of *Allium cepa* samples, the highest concentration of lead was determined in comparison with other metals. Steamed and sous-vide samples of *Allium cepa* had highest concentration of lead which was equal to 66 mg/kg. Compared to the lowest concentration, it was 1.3 times higher. The lowest concentration among the heavy metals was determined for cadmium, manganese and copper. Meanwhile, for boiled and sous – vide *Allium cepa,* content of copper 2.4 times was lower than for fried sample. The content of zinc in fried and boiled

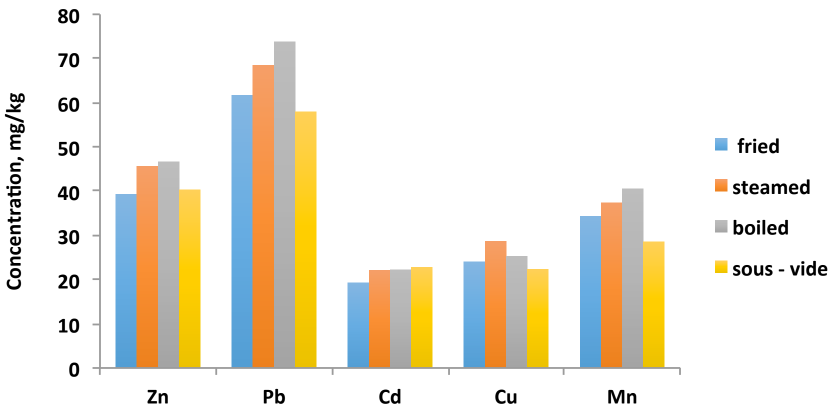

Figure 1 – Concentration of heavy metals in *Daucus carota subsp. sativus*

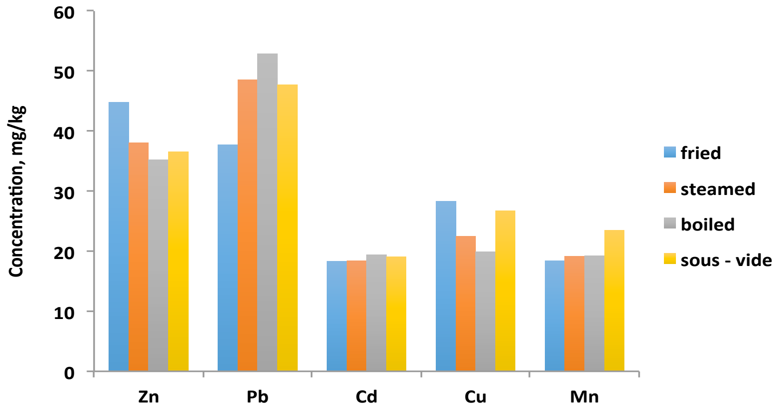

Figure 2 – Concentration of heavy metals in *Solanum tuberosum*

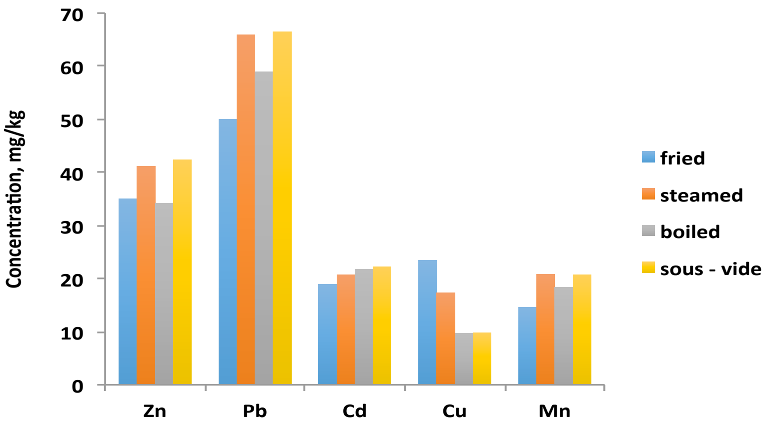

Figure 3 – Concentration of heavy metals in *Allium cepa*

sample of *Allium cepa* was equal, and 1.2 times lower comparing to steamed and sous – vide samples.

Out of all results, it can be concluded, that content of not all investigated heavy metals will depend on method of processing food. We can observe, weak correlation between content of lead, copper and manganese depending on method of processing of food.

3.2 Health Risk Index (HRI)

Risk assessment is helpful in estimating of possible health risk posed to human population which can be exposed by certain contaminants, including heavy metals, over a long period via daily dietary intake. Based on concentration of heavy metals in investigated samples, values of HRI were calculated.

In Table 1 it is seen that only two metals – lead and cadmium are exceeding of HRI value to dangerous values. In case of *Solanum tuberosum*, for all differently processed samples, HRI value of cadmium was significantly higher than 1. The same trend was seen for HRI value of lead for *Solanum tuberosum* samples. As a result, it indicated the possible health risk to human body in case of long period *Solanum tuberosum*

Table 1 – HRI of heavy metals

HRI	Zn	Pb	Cd	Cu	Mn
Daucus carota subsp. Sativus					
Fried	0	1.1	1.5	0	0
Steamed	0	1.3	1.7	0	0
Boiled	0	1.4	1.7	0	0
Sous-vide	0	1.1	1.1	0.2	0
Allium cepa					
Fried	0	1	1.4	0	0
Steamed	0	1.2	1.6	0	0
Boiled	0	1.1	1.7	0	0
Sous-vide	0	1.2	1.7	0	0
Solanum tuberosum					
Fried	0	3.4	6.8	0.2	0.2
Steamed	0	4.4	6.8	0.2	0.2
Boiled	0	4.9	7.1	0.1	0.2
Sous-vide	0	4.3	7.0	0.2	0.2

consumption. However, in case of HRI value of lead for *Solanum tuberosum*, the highest value was calculated for boiled samples, while the lowest value was indicated in fried ones, which means that, we can insignificantly reduce exposure of lead by choosing the method of processing food.

For *Daucus carota subsp. sativus* and *Allium cepa* samples, HRI value of cadmium and lead was slightly higher than 1. HRI value of zinc, copper and manganese for all investigated samples were less than 1, which indicates no health risk to human.

4. Conclusion

The high concentration of lead was determined in all investigated samples among the heavy metals. In *Solanum tuberosum* and *Daucus carota subsp. Sativus*, the high concentration of lead was determined for boiled samples; meanwhile for other samples of *Solanum tuberosum* and *Daucus carota subsp. Sativus* with different applied processing method the same value was slightly low.

HRI of cadmium and lead in *Solanum tuberosum* samples are significantly exceeding one. The highest value of HRI of lead was calculated for boiled *Solanum tuberosum*, while the lowest value was indicated in fried, which means that, we can insignificantly reduce exposure of lead by choosing the method of processing food.

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