REVIEW ARTICLE

The Effect of Rinsing, Soaking and Cooking Method on Level of Lead and Cadmium in Consumed Rice in Iran: A Systematic Review and Meta-analysis

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Abstract

Background: Considering the high levels of heavy metals in Iranian rice, it is required to take measures to reduce them. One of these measures is to soak or rinse the rice before cooking, which is done in two ways in Iranian cuisine: Kateh (traditional) and Pilaw.

Methods: This systematic review and meta-analysis aimed to find the best Iranian rice recipe for reducing Cadmium (Cd) and Lead (Pb) and compare the levels of these metals in Iranian and imported rice consumed in Iran. In this study the data were found from international and national databases from 2002 to 2022. 66 non-duplicate articles were found, eight review articles, and 47 unrelated articles were removed. The remaining 11 eligible articles were studied in terms of the types of heavy metals. Considering that Pb and Cd were investigated in most of the articles, these two metals were considered for this research. Begg's test was used to check the risk of bias.

Results: A total of 7 articles were finally selected, and the information was analyzed in Stata software. Based on Begg's test, no sign of publication bias was found. According to the results, Pb levels decreased in cooking methods compared to Cd, and their average reached 0.00 mg/kg. Also, the results showed that soaking or rinsing raw rice before cooking reduced Cd and Pb levels in the Pilaw method more than in the Kateh method (except for two exceptions).

Conclusion: Based on this study, it is preferable to avoid importing low-quality rice with high levels of heavy metals. Also, more attention should be paid to rice cultivation in Iran to reduce the concentrations of these metals and, to reduce heavy metals, the best method is to soak the rice for a few hours before cooking, discard the water and cook it using the Pilaw method.

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Keywords: Meta-analysis, Iran, Rice, Lead, Cadmium

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Introduction

Rice is the second most consumed food in Iran and one of the most essential grains in the world[1]; it is the commonest crop farmed in northern Iran.[2] The annual rice consumption in Iran is 3.2 million tons, of which 66.8% is produced domestically and 33.2% is imported. The most imported rice is from India, Pakistan, and Thailand.[3,4] Rice contamination with heavy metals has caused global concern.[5] It can be contaminated with

a lot of pollutants, including toxic metals like Arsenic (As), Aluminium (Al), Cadmium (Cd), Mercury (Hg), Chromium (Cr), and Lead (Pb), through the soil, water, and climatic conditions.[6-9] Unlike organic pollutants, heavy metals are non-degradable and accumulate in the soil and water sources; as a result, they accumulate in different parts of the rice plant, from the roots to the rice seeds.[10] Human activities, such as irrigation with sewage, animal and chemical fertilizers, pesticides, industrial activities, and increasing urbanization, cause contamination of agricultural products with heavy metals.[11-17] Research has shown that rice can absorb heavy metals such as Cd, Pb, and As in paddy fields compared to other grains.[18]

Studies in Iran have shown that certain types of rice do not meet national and international standards for heavy metal content.[19-22] Heavy metals can cause many diseases. The most important heavy metals that have adverse effects on health include Cd, Hg, Pb, As, and Nickel (Ni).[23, 24]

Some systematic reviews found that Cd, Cr, Pb, and As concentrations in rice were higher than the ISIRI (Institute of Standards and Industrial Research of Iran) standard limit.[1, 25] A meta-analysis showed that rice consumers in Iran were at high risk of carcinogenesis in terms of As and Pb levels.[26]

Soaking or rinsing raw rice before cooking and various types of cooking, including Kateh and Pilaw (Polo), can reduce heavy metals.[27-29] In Iran, rice is cooked in two ways. In the Pilaw method, rice is soaked or rinsed and then boiled with a large amount of water; after that, the water is removed, and the rice is cooked. In the second method, Kateh or the traditional method, rice is soaked or rinsed, then boiled with a small amount of water and cooked without removing its water.

The most important effective parameters that can affect rice contaminants include soaking time in water, washing time, cooking method, etc.[29-31] A study showed that washing and soaking in the rinse method (Pilaw) significantly decreased potassium (K) and Al levels compared to the traditional method (Kateh).[32] Also, as the rice soaking time increased from 1 to 12 hours, the reduction of heavy metals increased.[33] In another study, Pb levels decreased after cooking. In addition, the amount of Pb in Pilaw was lower than that in Kateh.[34] A study showed that the combination of washing three times and soaking for six hours before cooking rice had the most significant effect on reducing heavy metals.[35] However, a study observed that the effects of rice cooking methods on the reduction of heavy metal levels did not differ significantly.[28]

Given the high level of heavy metals in the rice consumed in Iran[1] and the high risk of carcinogenesis,[26] measures such as rinsing and soaking before cooking may reduce heavy metals.[33] Until now, no meta-analytical study has been conducted on comparing cooking methods, so this study aimed to resolve the contradictions in this case. This study used a systematic review and meta-analysis to find the best Iranian rice recipe for reducing heavy metals Cd and Pb and compare the amount of these metals in Iranian and imported rice consumed in Iran.

Methods

Analysis Method

The present study was a systematic review aiming to analyze the effects of cooking and rinsing or soaking on the reduction of Pb and Cd in rice consumed in Iran from 2002 to 2022.

Search Strategy

In 2022, the researchers investigated three international databases, including PubMed, Science Direct, Google Scholar, and the Iranian database SID. Keywords for international databases included rice, heavy metals, Iran, cooking, rinsing, and soaking. Persian keywords and similar searches were used to search the Iranian database.

Screening

The initial search for studies was conducted by the first and second authors. They independently screened the studies and evaluated the article quality control.

Inclusion and Exclusion Criteria

Review articles, studies that were not part of the original research, studies for which the abstract and full text were unavailable, studies that did not investigate the effect of cooking or soaking on the amount of heavy metals, and studies with unclear data were excluded from the pool of extracted studies. After reviewing the full text of eligible articles, all the studies that investigated the effect of cooking method, soaking, or rinsing on the amount of Pb and Cd in rice consumed in Iran were included.

Data Extraction

From each article, information including the author's name, number of samples, product brand, amount and type of heavy metal, cooking or rinsing method, confidence interval, place, and year was imported into Excel software. Also, the data were categorized and statistically analyzed. The information is given in Table 1.

Risk of Bias in the Studies

Begg's test was used with a significance level of 0.05 to investigate the risk of propagation bias using STATA version 13 statistical software.

Table 1: Information of included articles in the systematic review and meta-analysis

Reference	Prevalence (CI)	Food	Sample size	Heavy metal	Brand	Location
Fakhri et al., 2018[26]	0.0352(0.0345-0.0358)	Raw rinsed or soaked	60	Pb	Imported	Tehran
Fakhri et al., 2018[26]	0.0226(0.022-0.0231)	Pilaw	60	Pb	Imported	Tehran
Rezaei Malidareh et al., 2016[29]	0.58(0.0437-1.1162)	Raw rinsed or soaked	15	Cd	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	1.79(1.3548-2.2251)	Raw rinsed or soaked	15	Pb	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	3.94(3.2973-4.5826)	Pilaw	15	Cd	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	23.09(19.3654-26.8145)	Pilaw	15	Pb	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	0.27(0.2143-0.3256)	Pilaw	15	Cd	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	1.76(1.416-2.1039)	Pilaw	15	Pb	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	3.81(3.5389-4.0811)	Kateh	15	Cd	Iranian	Qaemshahr
Rezaei Malidareh et al., 2016[29]	19.29(15.6616-22.9183)	Kateh	15	Pb	Iranian	Qaemshahr
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Raw rinsed or soaked	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Raw rinsed or soaked	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Raw rinsed or soaked	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Raw rinsed or soaked	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Raw rinsed or soaked	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Raw rinsed or soaked	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Raw rinsed or soaked	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Kateh	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Kateh	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Kateh	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Pilaw	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Pilaw	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Kateh	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Kateh	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Pilaw	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Pilaw	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Kateh	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Kateh	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Pilaw	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Pilaw	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Kateh	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Kateh	45	Cd	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(-0.0001-0.0001)	Pilaw	45	Pb	Iranian	West of Gilan
Abbasi et al., 2020[35]	0(0-0)	Pilaw	45	Cd	Iranian	West of Gilan
Naseri et al., 2014[28]	0.096(0.0599-0.132)	Kateh	27	Cd	Imported	Shiraz
Naseri et al., 2014[28]	0.146(0.0911-0.2008)	Kateh	27	Cd	Imported	Shiraz
Naseri et al., 2014[28]	0.522(0.412-0.6319)	Kateh	27	Pb	Imported	Shiraz
Naseri et al., 2014[28]	0.063(0.0567-0.0692)	Kateh	27	Cd	Imported	Shiraz
Naseri et al., 2014[28]	1.072(0.951-1.1929)	Kateh	27	Pb	Imported	Shiraz
Naseri et al., 2014[28]	1.399(1.2984-1.4995)	Kateh	27	Pb	Imported	Shiraz
Naseri et al., 2014[28]	0.07(0.0553-0.0847)	Pilaw	27	Cd	Imported	Shiraz
Naseri et al., 2014[28]	0.088(0.0805-0.0954)	Pilaw	27	Cd	Imported	Shiraz
Naseri et al., 2014[28]	0.14(0.1337-0.1462)	Pilaw	27	Cd	Imported	Shiraz
Naseri et al., 2014[28]	0.696(0.5358-0.8561)	Pilaw	27	Pb	Imported	Shiraz
Naseri et al., 2014[28]	0.949(0.5668-1.3312)	Pilaw	27	Pb	Imported	Shiraz
Naseri et al., 2014[28]	1.295(1.2648-1.3251)	Pilaw	27	Pb	Imported	Shiraz
Zazouli et al., 2010[34]	10.3(8.8102-11.7897)	Kateh	72	Pb	Iranian	Babol
Zazouli et al., 2010[34]	3.45(3.0921-3.8078)	Pilaw	72	Pb	Iranian	Babol
Jafari-Moghadam et al., 2015[39]	0.276(0.1976-0.3544)	Raw rinsed or soaked	600	Cd	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.978(0.7232-1.2328)	Raw rinsed or soaked	600	Pb	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.095(-0.5518-0.7418)	Raw rinsed or soaked	600	Cd	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.745(0.5098-0.9802)	Raw rinsed or soaked	600	Pb	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.186(0.088-0.284)	Raw rinsed or soaked	600	Cd	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.995(0.7794-1.2106)	Raw rinsed or soaked	600	Pb	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.153(0.0726-0.2333)	Pilaw	600	Cd	Imported	Tehran
Jafari-Moghadam et al., 2015[39]	0.825(0.5702-1.0798)	Pilaw	600	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.08(0.0619-0.098)	Raw rinsed or soaked	54	Cd	Iranian	Tehran
Sharafi et al., 2019[33]	0.069(0.0623-0.0756)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.142(0.1069-0.177)	Raw rinsed or soaked	54	Cd	Imported	Tehran

Reference	Prevalence (CI)	Food	Sample size	Heavy metal	Brand	Location
Sharafi et al., 2019[33]	0.079(0.0611-0.0968)	Raw rinsed or soaked	54	Cd	Iranian	Tehran
Sharafi et al., 2019[33]	0.068(0.0617-0.0742)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.142(0.1069-0.177)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.079(0.0609-0.097)	Raw rinsed or soaked	54	Cd	Iranian	Tehran
Sharafi et al., 2019[33]	0.064(0.0577-0.0702)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.138(0.1038-0.1721)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.069(0.0531-0.0848)	Raw rinsed or soaked	54	Cd	Iranian	Tehran
Sharafi et al., 2019[33]	0.058(0.0531-0.0629)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.124(0.0932-0.1547)	Raw rinsed or soaked	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.071(0.0537-0.0882)	Kateh	54	Cd	Iranian	Tehran
Sharafi et al., 2019[33]	0.052(0.0471-0.0569)	Kateh	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.13(0.0943-0.1656)	Kateh	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.057(0.0446-0.0693)	Pilaw	54	Cd	Iranian	Tehran
Sharafi et al., 2019[33]	0.054(0.0487-0.0592)	Pilaw	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.109(0.0813-0.1366)	Pilaw	54	Cd	Imported	Tehran
Sharafi et al., 2019[33]	0.043(0.0375-0.0484)	Raw rinsed or soaked	54	Pb	Iranian	Tehran
Sharafi et al., 2019[33]	0.137(0.115-0.1589)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.675(0.5599-0.79)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.04(0.0351-0.0449)	Raw rinsed or soaked	54	Pb	Iranian	Tehran
Sharafi et al., 2019[33]	0.131(0.11-0.1519)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.648(0.5354-0.7605)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.039(0.0342-0.0437)	Raw rinsed or soaked	54	Pb	Iranian	Tehran
Sharafi et al., 2019[33]	0.122(0.1029-0.141)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.584(0.4825-0.6827)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.028(0.0238-0.0321)	Raw rinsed or soaked	54	Pb	Iranian	Tehran
Sharafi et al., 2019[33]	0.095(0.0793-0.1106)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.411(0.3361-0.4858)	Raw rinsed or soaked	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.032(0.0278-0.0361)	Kateh	54	Pb	Iranian	Tehran
Sharafi et al., 2019[33]	0.106(0.0895-0.1224)	Kateh	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.62(0.4947-0.7452)	Kateh	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.023(0.0212-0.0247)	Pilaw	54	Pb	Iranian	Tehran
Sharafi et al., 2019[33]	0.088(0.0717-0.1042)	Pilaw	54	Pb	Imported	Tehran
Sharafi et al., 2019[33]	0.427(0.3617-0.4922)	Pilaw	54	Pb	Imported	Tehran

Heavy metals: Pb: Lead, and Cd: Cadmium. CI: Confidence Interval

Statistical Analysis

To evaluate the degree of heterogeneity of the included studies, the chi-square test was used with a significance level of 0.05, I^2>50%. In the case of heterogeneity, a random effect model with an inverse variance method was used. Otherwise, the fixed-effect model was used. All analyses were performed using STATA version 13 statistical software.

Results

Systematic Review

• Search results and selection of study

After searching all international and national databases, 66 non-duplicate articles were obtained, eight review articles, and 47 unrelated articles were removed. The remaining 11 articles were studied in terms of the types of heavy metals. Given that Pb and Cd were investigated in most of the articles, these two metals were considered for this research. Also, studies with inaccurate reports on the number of heavy metals were excluded. A total of seven articles were approved and entered the final analysis. The flow chart of the included studies is displayed in Figure 1.

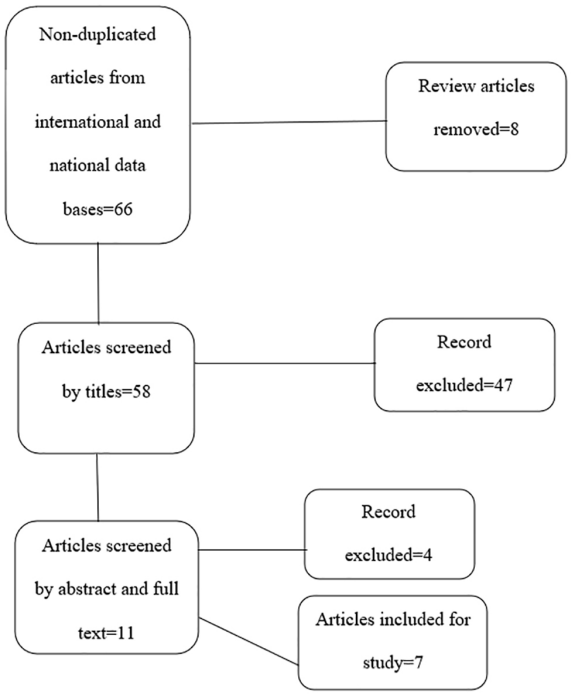

Figure 1: Flowchart of the included eligible studies in systematic review and meta-analysis

Table 2: Lead and Cadmium concentrations in Iranian and imported rice

	Cadmium		Lead	
	Mean (mg/kg)	**95%CI**	**Mean (mg/kg)**	**95%CI**
Imported	0.10	0.09-0.11	0.33	0.31-0.35
Iranian	0.35	0.27-0.43	0.00	0.00-0.00

CI: Confidence Interval

Table 3: Lead and Cadmium concentrations in raw and cooked rice (Pilaw and Kateh)

	Cadmium		Lead	
	Mean (mg/kg)	**95%CI**	**Mean (mg/kg)**	**95%CI**
Pilaw	0.12	0.09-0.16	0.00	0.00-0.00
Kateh	0.22	0.17-0.28	0.00	-0.00-0.00
Raw rinsed or soaked	0.09	0.08-0.10	0.00	0.00-0.00

CI: Confidence Interval

• Characteristics of the studies and extracted data

The results of different studies on Cd and Pb residues in different types of rice are shown in Table 1. Cd was investigated in five studies and Pb in seven studies. Rezaei Malidareh et al.[29] found the highest concentration of Pb, 23.09 mg/kg, in rice prepared using the Pilaw method. Also, the lowest amount (0 mg/kg) related to Pb and Cd in raw Iranian rinsed or soaked rice, Pilaw, and Kateh was reported by Abbasi et al.[35]

Meta-analysis Results

• The effect of brand on Pb and Cd residues in rice consumed in Iran

The results of the meta-analysis showed that the amount of Pb in Iranian rice was 0.00 mg/kg (CI 95%: 0.00, 0.00) and in imported rice consumed in Iran was 0.33 mg/kg (CI 95%:0.31, 0.35). Also, the amount of Cd in Iranian rice was 0.35 mg/kg (CI 95%:0.27, 0.43) and in imported rice consumed in Iran was 0.10 mg/kg (CI 95%:0.09, 0.11), as shown in Table 2.

• The effect of cooking method on the amount of Pb and Cd in the rice consumed in Iran

The meta-analysis found that Pb levels in Pilaw, Kateh, and raw rinsed or soaked rice were all 0.00 mg/kg (CI 95%: 0.00, 0.00). The Pilaw method yielded 0.12 mg/kg of Cd (CI 95%: 0.09, 0.16), the Kateh method 0.22 (CI 95%: 0.17, 0.28) and raw rinsed or soaked rice

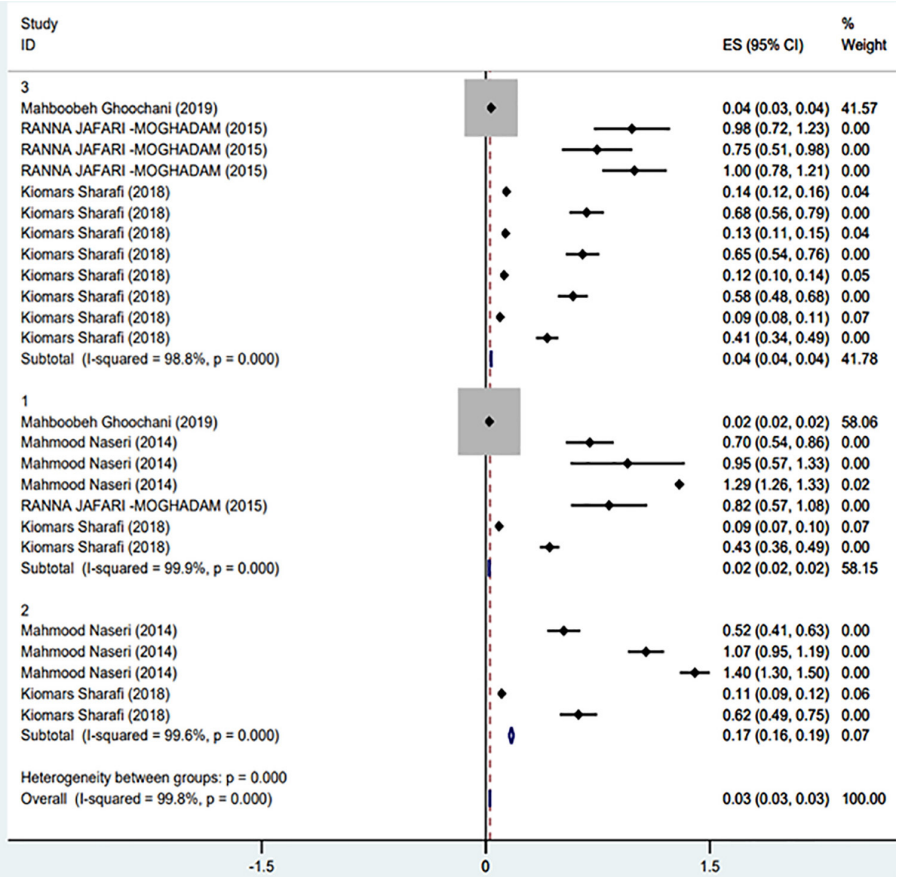

Figure 2: Lead concentrations in imported raw and cooked rice (1: Pilaw, 2: Kateh, 3: raw rinsed or soaked rice)

0.09 (CI 95%: 0.08, 0.10), as shown in Table 3.

• The effect of cooking methods on the amount of Pb and Cd in imported rice

The results of the meta-analysis showed that the amount of Pb in imported rice Pilaw was 0.02 mg/kg (CI 95%: 0.02, 0.02), in imported rice Kateh was 0.17 mg/kg (CI 95%: 0.16, 0.19), and in imported raw rinsed or soaked rice was 0.04 mg/kg (CI 95%: 0.04, 0.04), as displayed in Figure 2. Also, as shown in Figure 3, the amount of Cd in imported rice Pilaw was 0.10 mg/kg (CI 95%: 0.06, 0.13), in imported rice Kateh was 0.08 mg/kg (CI 95%: 0.06, 0.10), and in imported raw rinsed or soaked rice was 0.10 mg/kg (CI 95%: 0.08, 0.11).

• The effect of cooking methods on the amount of Pb and Cd in Iranian rice

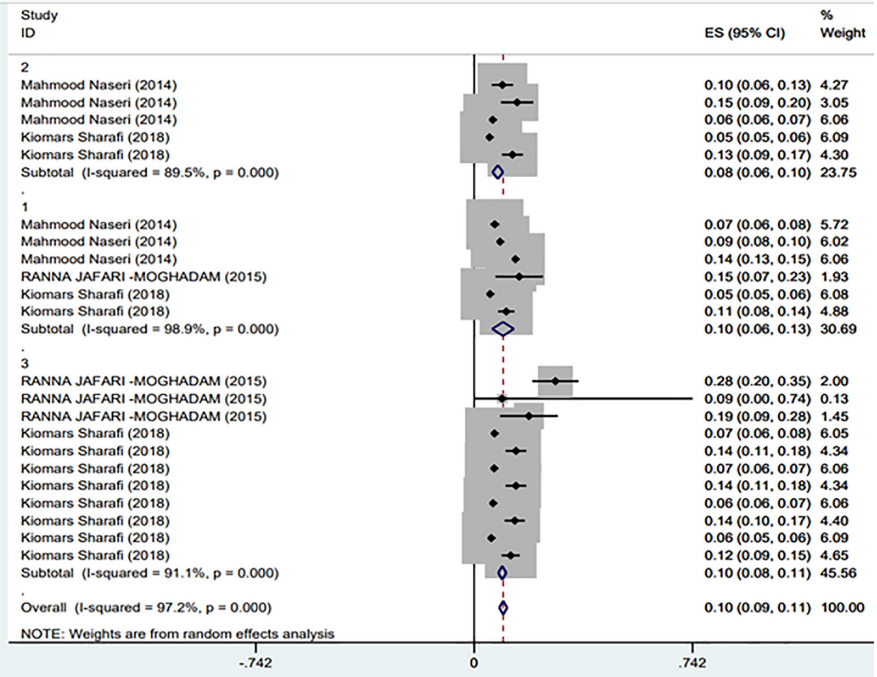

Figure 3: Cadmium concentrations in imported raw and cooked rice (1: Pilaw, 2: Kateh, 3: raw rinsed or soaked rice)

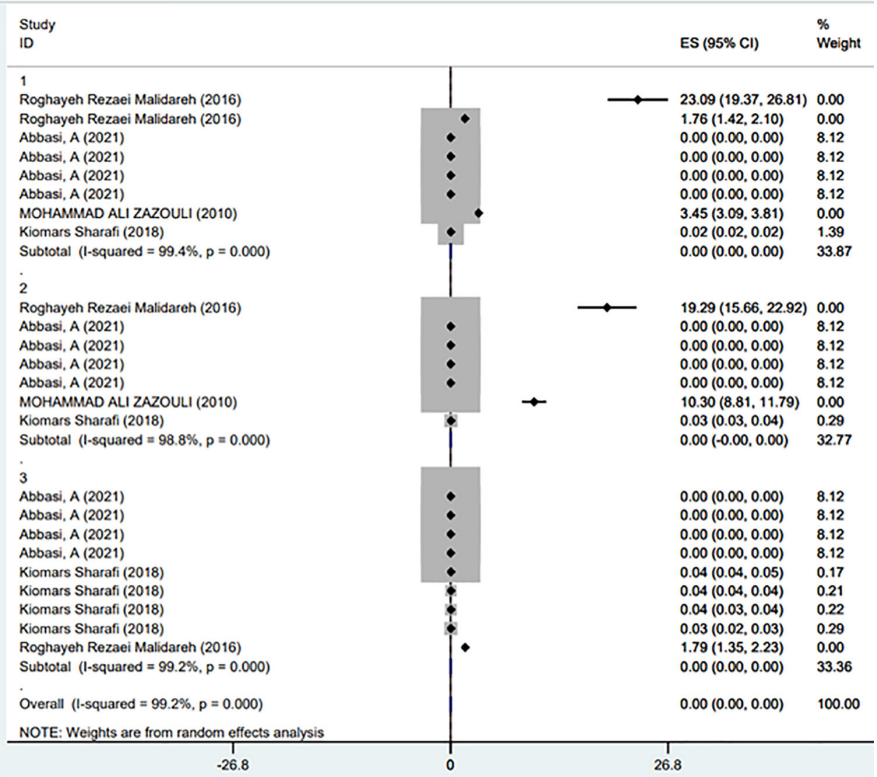

Figure 4: Lead concentrations in Iranian raw and cooked rice (1: Pilaw, 2: Kateh, 3: raw rinsed or soaked rice)

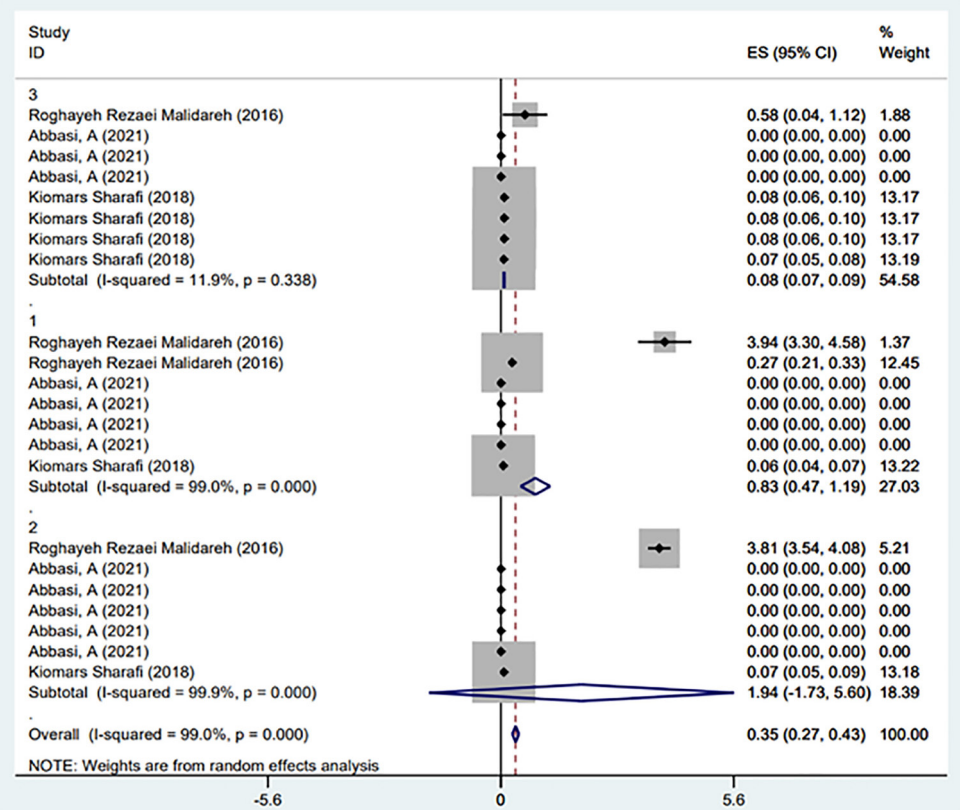

Figure 5: Cadmium concentrations in Iranian raw and cooked rice (1: Pilaw, 2: Kateh, 3: raw rinsed or soaked rice)

The results of the meta-analysis showed that the amount of Pb was 0.00 mg/kg (CI 95%: 0.00, 0.00) in Iranian rice Pilaw, 0.00 mg/kg (CI 95%: -0.00, 0.00) in imported rice Kateh, and 0.00 mg/kg (CI 95%: 0.00, 0.00) in imported raw rinsed or soaked rice was. It is shown in Figure 4. Also, the amount of Cd was 0.83 mg/kg (CI 95%: 0.47, 1.19) in imported rice Pilaw, 1.94 mg/kg (CI 95%: -1.73, 5.60) in imported rice Kateh, and 0.08 mg/kg (CI 95%: 0.07, 0.09) in imported raw rinsed or soaked rice, which is shown in Figure 5.

Risk of Bias in Studies

Based on the Begg's test (p>0.05), no indication of publication bias was found between studies.

Discussion

The present study focused on comparing cooking methods to reduce the levels of Cd and Pb in Iranian and imported rice consumed in Iran. The amount of Cd in imported and Iranian rice consumed in Iran was 0.10 and 0.35 mg/kg, respectively. Also, the amount of Pb in imported and Iranian rice consumed in Iran was 0.33 and 0.00 mg/kg, respectively. The results showed that the amount of Cd in Iranian rice was higher than that in imported rice, but the amount of Pb in imported rice was higher than that of Iranian rice (Table 2). These results were similar to a meta-analysis conducted on raw rice, where the average concentration of Cd and Pb in Iranian/imported rice was 0.16±0.08 /0.13±0.05 and 0.196±0.16 /0.55±0.56 mg/kg, respectively.[36]

The difference in the amount of metals in Iranian and imported rice may be due to various reasons, including the amount of organic compounds and proteins in rice (to form complexes with metals), the strength and resistance of the surface layer of rice grains against water penetration (during washing and cooking) surface or deep pollution of rice grains with metals and so on.[33] The results showed that Pb decreased more than Cd in cooking methods, and its average reached 0.00 mg/kg (Table 3, Figures 2-5). This may be because the soil and roots of plants such as rice could absorb and stabilize Pb, resulting in lower Pb levels in the rice grain. Therefore, it can be concluded that the distribution of Pb in rice is mainly superficial, and the methods of cooking, soaking, and rinsing reduce the amount of Pb more than Cd.[33] Also, the results showed that the effects of cooking and soaking or rinsing raw rice on the reduction of Cd and Pb were, respectively, soaked or rinsed raw rice> Pilaw rice > Kateh rice (Table 3, Figures 4, 5). Except for Figs 2 and 3 in which the amounts of Pb in imported rice Pilaw, Kateh, and soaked or rinsed raw rice were respectively 0.02, 0.17, and 0.04 mg/kg, the amount of Cd in imported rice Pilaw, Kateh, and soaked or rinsed raw rice were respectively 0.10, 0.08, 0.10 mg/kg. These exceptions can be ignored because of the difference of Pb in imported raw rinsed or soaked rice and Pilaw, and the difference between Cd in imported Pilaw or rinsed-soaked raw rice and

Kateh was 0.02 mg/kg, which was very small.

The reason that the number of heavy metals in rinsed or soaked raw rice was lower than that of cooked rice could be that in some studies whose data were included in the meta-analysis, the rice was soaked for up to 12 hours. However, usually, in the cooking methods, rice is not soaked for so long before cooking. The results of a study have shown that the removal of metals increases with soaking time. The main reason is that the rate at which water penetrates the rice increases as the soaking period increases (that is, as the contact time between the rice and water increases). Hence, more metals are dissolved in the water, and eventually, the water containing the metals is thrown away.[30] Also, the results of studies have shown that soaking more than rinsing reduces heavy metals, and the longer the soaking time, the greater the reduction of heavy metals.[33] The reason is that, in the rinsing process, the water only comes into contact with the surface of the rice. As a result, in this process, unlike the soaking process, water cannot penetrate the inner layers that contain heavier metals.[37]

Based on the results of this study, the Pilaw method was more effective in removing heavy metals than the Kateh method. The main reason for this difference is that in the Pilaw method, the water in which the rice is boiled is thrown away because the remaining water after the cooking process contains a certain number of heavy metals that dissolve in the water.[9, 38]

The strength of this study was that no meta-analytical research has been conducted on the effect of cooking methods, rinsing, and soaking on the reduction of heavy metals in consumed rice in Iran, and this is the first meta-analytical study in this regard. One of the weaknesses of this research was that only cooking methods and soaked or rinsed raw rice were compared, and raw rice was not included in this study. The reason was that many studies have been conducted on raw rice in Iran, but few studies have been conducted on cooked rice. Therefore, comparing the averages would not be accurate if raw rice data were also included.

Conclusion

The widespread consumption of rice laden with heavy metals in Iran requires measures to be taken by authorities. It is better to avoid the import of low-quality rice that has high heavy metals. For reducing these metals, more attention should be paid to the field of rice cultivation in Iran (especially irrigation sources, pesticides, and fertilizers). Also, the best method for reducing heavy metals is to soak the rice for several hours before cooking, discard the water, and cook it using the Pilaw method.

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Authors' Contribution

NM: Record searching, Data extraction, Quality assessment, Resources, Writing – original draft, Writing – review & editing. AA: Quality assessment, Project administration, Resources, supervision, review & editing. EB: Software, Quality assessment, review & editing.

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Conflict of Interest

None declared.

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