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RESEARCH PAPER

# Determination of some heavy metals in imported rice grains (*Oryza sativa*) available in Sulaymaniyah market and evaluation of their health risk assessment

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**A B S T R A C T:**
This investigation was carried out to determine the levels of several heavy metals, including As, Pb, Cd, Zn, Cr, Fe, Mn, Ni, and Cu in imported rice sold in Sulaymaniyah markets, Iraqi Kurdistan Region. Estimated Weekly Intake (EWI) for each heavy metal from rice consumption were calculated, and the results were compared to the Provisional tolerable Weekly Intake (PTWI) to evaluate the potential health risk assessment. The values of Cu, Mn and Zn were significantly higher than allowable limits set by FAO/WHO but the Pb value was lower than allowable limits except (Uruguayan rice R9 and R12, Iranian rice R20, American rice R24, and Russian rice R26). The Cr value was within the safe limit except for brands (Indian rice R1, Uruguayan rice R12, Iranian rice R20, Chinese rice R33), which were higher than the allowable limit. The EWI for Ni in most samples were higher than the PTWI except (Turkish rice R13, Russian rice R25 and R27, and Chinese rice R29). Estimated Weekly Intake for Cr in nearly twenty one rice samples were lower than the PTWI limits. Also, the EWI for Zn, Mn and Cu were higher than the PTWI limits. Additionally, the EWI for Pb was much greater than other heavy metals evaluated. Thus, the high daily intake of rice contaminated with heavy metals could cause potential health hazards to the consumers in Kurdistan. More consideration should be assumed to imported rice and then prevention and control measures should be taken.

KEY WORDS: Rice, Imported Rice, Heavy Metals, Health Risk Assessment, Estimated Weekly Intake.
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## 1. INTRODUCTION:

Rice is a staple food for the population of Iraq and Kurdistan Region, and that is why the need for imported rice is increased year by year. Rice is serving as a most common cereal food for approximately half of the global population. About 80% of the required daily energy of Asia`s people (2 billion population) derive only from rice (Chaudhari *et al.*, 2018). The health risks associated with long-term rice consumption containing heavy metals should be considered because they can accumulate in food systems through growing soil and contaminated water, which has grown to be a major issue in recent years (Lokeshwari and Chandrappa, 2006).

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Heavy metals are a relatively high density group of metals and metalloids that are toxic even at low levels (Gautam *et al.*, 2014). They include of cadmium (Cd), lead (Pb), mercury (Hg), zinc (Zn), arsenic (As), iron (Fe), nickel (Ni), copper (Cu), and chromium (Cr). Toxic elements, also defined as heavy metals, may have negative effects on living organisms and the environment, and tend to bio accumulate in humans, after continued exposure which causes various negative health effects (Jaishankar *et al.*, 2014). There are natural and human-made sources of heavy metal emissions into the environment, including industrial discharges, mining, and vehicle exhaust (Alloway, 2013), they are also originated from the use of phosphate fertilizers in agricultural and sewage sludge (Chen *et al.*, 2016).

According to several studies, rice contains heavy metals including As, Pb, Cd, and Hg (Fu *et al.*, 2015). Heavy metals such as Zn, Cr, Cu, Fe, and Mn are required for human physiological function in extremely small concentrations (Wuana and Okieimen, 2011). The frequent exposure to heavy metals from consuming rice have a major impact on mental disorders and another health issues due to luck of human body to detoxify them (Castro-González and Lima, 2016). However, heavy metals are vital for normal plants growth but they become poisonous in high quantities, they are also capable of being absorbed by plants, which can subsequently be consumed by people through food system (Guo *et al.*, 2020).

The international agency for research on cancer has already classified Pb as carcinogenic, and continuous exposure to low amounts of it can impair the immune system, kidneys, and genital system permanently (Tchounwou *et al.*, 2012). In addition, Fe is essential for the transfer of oxygen and the production of hemoglobin (Vogt *et al.*, 2021). Health concerns about Ni contamination in food and should not be neglected, as Ni combined with other harmful active compounds in the human body system can cause severe poisoning (Valko, Morris and Cronin, 2005).

Rice is a major part of the Kurdish diet. It is estimated around 85% of rice consumed in Iraq and the Kurdistan Region is imported. Most of these imported rice comes from India, Kazakhstan, Russia, Pakistan, Vietnam, Uruguay, the USA, Thailand, Turkey, and Iran, and over 100 companies are involved in importing rice. According to the Kurdistan Region Government (KRG) Planning and Follow-Up Department of the Ministry of Trade and Industry, more than one million metric tons of rice are imported into Iraq and the Kurdistan region each year. The ministry estimates that each people consumes 38.5 kg of rice each year.

Thus, the main objectives of this research were to (i) measure the concentrations of some heavy metals, including As, Pb, Cd, Cr, Cu, Zn, Fe, Ni), and Mn in the imported rice sold in Sulaymaniyah markets, Iraqi Kurdistan, (ii) the results will compare to the FAO/WHO-established acceptable limits, and (iii) determine the Preliminary Tolerable Weekly Intake (PTWI) suggested by the Joint FAO/WHO Expert Committee on Food Additives is contrasted with the EWI of the studied heavy metals in the selected rice samples.

## 2. Materials and Methods

### Sample collection

A total of thirty-three types of commonly imported rice samples were randomly collected from the locally retail markets and the other famous hyper markets in Sulaymaniyah city includes (Family Mall, Majidi Mall, Show Market, and Sulaymaniyah Weekly Market), representing local consumer preferences and from ten major groups according to the country of origin and based on their popular consumption in Iraqi Kurdistan Region. The code of rice samples were placed depending on the country of origin were: Indian rice (R1, R2, R3, R4, R5, and R6), Uruguayan rice (R7, R8, R9, R10, R11, and R12), Turkish rice (R13 and R14), Kazakh rice (R15), Thailand rice (R16, R17, and R18), Iranian rice (R19 and R20), Pakistani rice (R21 and R22), American rice ( R23 and R24), Russian rice ( R25, R26, R27 and R28), and Chinese rice (R29, R30, R31, R32, and R33). They were purchased in their original imported packages (25, 10, 5 and 1 kg), then 1 kg from each samples kept in a plastic zip bag and stored until analysis.

### Samples preparation and analysis

Rice samples were passed through 355 µm sieve (prufsieb – ISO 3310-1) to reduce flour to remain fine fractions to ensure nonappearance of any imperfections, and sifting to get desired flour. The rice samples were stored at room temperature until analysis.

All rice samples were ground into a fine powder using a stainless steel grinder (COF-3820) before digestion. Approximately 1 g of milled rice samples were placed into 50 mL beaker and digested in 10 mL of 65% nitric acid ($HNO_3$) solution, followed by heating at 150 °C for 1 h, until clear solution produced. Following cooling, and then filtered by using 45µm size Whatman filter paper. Prior to analysis, the digested samples were diluted with deionized water to a final volume of 25 ml and stored at 4 °C (Payus and Talip, 2014). The heavy metals concentrations were determined in digested samples using Inductivity Coupled Plasma Optical Emission Spectrometry (ICP-OES) module (PerkinElmer – America).

### Health risk assessment

For the Kurdistan population, the EWI of heavy metals has been computed. In order to evaluate the potential human health risk assessment, the following equation reported by (Onsanit *et al.*, 2010).

The estimated weekly intake of heavy metals from consuming rice was taken into account while assessing the potential risk to human health, and the calculated values were compared to the PTWI. The EWI was calculated using the following equation:

$$EWI = C * \frac{WC}{BW}$$

Where, EWI is estimated weekly intake (mg $kg^{-1}$ body weight/week), C is the average of trace metal concentrations in rice (mg $kg^{-1}$ dry weight), WC is weekly rice consumption (g/week) per capita for the Kurdistan population (114.57 g per capita per day × 7) according to the KRG Planning and Follow-Up Department of the ministry of trade and industry. Weekly rice consumption (g per week) = 802 g, BW is the average of body weight in (kg) of the Kurdistan population (70 kg) (Tattibayeva *et al.*, 2016).

The values are given in mg/week/person.

**Statistical analysis**

The experiment findings are statistically analyzed using XLSTAT-pro (version 7.5.2) according to the analysis of variance (ANOVA) for the CRD design. Duncan test was used for significant differences between the parameters at $p \leq 0.05$.

## 3. Results and Discussion

**The heavy metal levels in imported rice**

High consumption of heavy metals lead to serious health problems. For example, anemia, high blood pressure, severe effects on brain, kidney, lung, bone, liver function, composition of blood and other important organs (Jaishankar *et al.*, 2014). In comparison to other cereals, particularly rice absorbs more As from contaminated irrigation water and paddy soil, as well as from other sources including pesticides and fertilizers (Kwon, Nejad and Jung, 2017). Depending on the country of origin, imported rice samples contained different amounts of heavy metals. The achieved values of As in rice samples were lower than <0.001 mg $kg^{-1}$ in all the studied rice samples which is lower than the safe limit set by (FAO/WHO), and regulations from the European Council and the Food and Drug Administration (FDA) specify a maximum residual level of inorganic As in rice at less than 0.2 mg $kg^{-1}$ (Abedin *et al.*, 2002).

Lead is a highly hazardous element, and even low amounts of exposure can causes a variety of health problems (Batista, Silvestre and Oliveira, 2012). The amount of Pb in the rice samples analysed in this investigation ranged from <0.001 to 1.750 to mg $kg^{-1}$. The highest level of Pb was found in Iranian rice R20 (1.750), followed by (1.700, 0.525, 0.475) in R12, R24, and R26, respectively. Except for the samples mentioned above, where the average Pb concentrations were higher than the level set by FAO/WHO standards (0.2 mg/kg). According to the results found in China by (Yu *et al.*, 2016) the level of Pb ranged from (0.034–0.076 mg $kg^{-1}$). Additionally, in a study by (Naseri *et al.*, 2015) in Iran, the mean Pb levels in domestic and imported rice samples were both significantly higher than the FAO/WHO limit. The Pb levels in imported rice samples ranged from 0.76 to 2.00 mg $kg^{-1}$, and s in domestically grown rice samples ranged from 0.71 to 1.28 mg $kg^{-1}$.

Cadmium content in rice samples were not detected due to the cause of use of ICP-OES to determine Cd. The obtained data of Cd were also negative and the element is not present at the detection limit. However, it has been stated in several studies that the concentration of Cd for imported rice grains were between 0.27-0.48 mg $kg^{-1}$ and 0.004-0.19 mg $kg^{-1}$ in Iran and Jamaica, respectively (Antoine *et al.*, 2012). In similar with this study, studied conducted in several region in Iran, Cd does not detected in rice samples (Noll *et al.*, 2005). In contrast, in another study conducted in Kingdom of Saudi Arabia, the Cd was detected in 37 imported rice varieties and the result was above the standard limits. However, it has been confirmed that soaking and rinsing rice grains with water has been showed to help reduce Cd to acceptable levels. They discovered that washing rice with citric acid reduced the amount of Cd by more than 95% because the link between the metal and the rice protein was disrupted, another reason is that most divalent elements (cation +) are located in the outer layer of grain which can be released into washed water (Al-Saleh, Abduljabbar and health, 2017).

According to Codex Alimentarius Commission (CAC), the authorized limit for Zn in rice grain is (Null) or should not be accessible, but in the present study, the highest concentration of Zn was 18.63 mg $kg^{-1}$ obtained in R7 and the lowest was 3.975 mg $kg^{-1}$ in an R2. The concentrations of Zn in complete imported rice samples were higher than the recommended maximum tolerance value which is (Null) set by FAO/WHO. In comparison, the study conducted by (Guadie *et al.*, 2022), the Zn values in the rice samples ranged from 22.01 to 27.37 mg $kg^{-1}$ in Pawe and Jimma White rices respectively, and the findings showed that rice imported from Pakistan and India had the lowest and highest Zn levels, respectively. In a different investigation, rice samples from two locations of Vietnam had Zn concentrations ranging from 5.341 to 11.653 mg $kg^{-1}$ (Chu *et al.*, 2021).

While the highest concentration of Cr was determined in R33 Chinese rice (12.88 mg $kg^{-1}$), the lowest was zero in R7. The mean Cr values in most of the samples were lower than the FAO/WHO allowable limits which is (1 mg $kg^{-1}$) except for these (R1, R12, R19, R20, and R33,). According to a study conducted in Ethiopia, Cr levels in imported rice were 4.82 mg $kg^{-1}$ in an Indian rice, 5.56 mg $kg^{-1}$in a Pakistani rice, and 11.02 mg $kg^{-1}$in a Korean rice (Guadie *et al.*, 2022).

The highest concentration of Fe was found in the R20 (6357 mg $kg^{-1}$) and lowest in the R6 (5.175 mg $kg^{-1}$). The Fe contents in (R7, R8, R9, R12, R17, R20, R24, and R26) exceeded the acceptable limit. However, in the remaining brands, the values of Fe were lower than the limit set by FAO/WHO (450 mg $kg^{-1}$). The results is similar to the study conducted in turkey, they found that the concentration of Fe was (5.06 mg $kg^{-1}$) in rice purchased from the local market (Demirel *et al.*, 2008). In contrast, a study conducted on imported rice in Iraq, the concentration of Fe was in the range of 0.399 mg $kg^{-1}$in American basmati rice to 2.723 mg $kg^{-1}$in Basmati rice (Southern Iraqi company) (Almayahi and Aljarrah, 2020).

In terms of Mn contents, R12 had the highest amount 23.53 mg $kg^{-1}$, whereas R2 had the lowest level of 0.725 mg $kg^{-1}$. Except for R2, all rice samples had mean Mn values above the acceptable limits set by the FAO/WHO (1 mg $kg^{-1}$). According to a study performed in Vietnam by (Chu *et al.*, 2021), Mn levels in rice samples ranged from 7.4 to 42.65 mg $kg^{-1}$, exceeding the permitted limits.

In the present study, the concentration of Ni was observed to be highest in R33 (6.175 mg $kg^{-1}$), and the lowest level was <0.001 mg $kg^{-1}$ in the rice samples (R13, R25, R27, and R29,). The mean of Ni contents in the rice samples such as (R13, R14, R21, R16, R21 R25, R27, R29, R30, R31, and R32) was lower than the acceptable limit set by FAO/WHO (0.1 mg $kg^{-1}$). According to these findings, a study performed in Nigeria revealed that the levels of Ni in rice samples imported from Thailand and India ranged from 0.05 to 6.05 mg $kg^{-1}$, respectively (Emumejaye, 2014). However, (Naseri *et al.*, 2015) studied Ni concentrations in imported rice samples from Thailand and India and found that the Ni concentration ranged from of 0.67 to 0.89 mg $kg^{-1}$, respectively.

The highest concentration of Cu was 7.20 mg $kg^{-1}$ in R23 and the lowest level was 0.325 mg $kg^{-1}$ in R2. Meanwhile, the (FAO/WHO, 2002), allowable limits for Cu set at (Null) in rice grain. All samples of imported rice used in the current study had Cu levels that exceeded the allowable limit. These results are consistent with those found in a study conducted in Vietnam, where it was stated that the Cu content ranged between 0.118 and 7.754 mg $kg^{-1}$(Chu *et al.*, 2021). Additionally, imported rice from Pakistan with a Cu content of 7.0 mg $kg^{-1}$ and imported rice from Thailand with a Cu content ranging from 2.14 to 3.01 mg $kg^{-1}$ were both found in Malaysia (Abd Rashid *et al.*, 2018).

**Estimated weekly intake of heavy metals from consumption of imported rice**

According to our findings, rice consumption that has been contaminated with heavy metals could be harmful to the local population's health. The WHO and FAO organizations have published heavy metals intake guidelines by human, thus we utilized the EWI based on the average values for each heavy metal in rice. According to the KRG Planning and Follow-Up Department of the Ministry of Trade and Industry, the average weekly consumption of rice is 802 g in Kurdistan, and the average body weight (BW) of an adult is 70 kg.

For all the imported rice samples, the EWI of As were <0.011 mg $kg^{-1}$. These levels were below the PTWI of 0.015 mg $kg^{-1}$. The EWI for Pb was significantly higher than the heavy metals measured, which is shown in (Table 2). The EWI of Pb in the all imported rice samples ranged from <0.011 to 20.05 mg $kg^{-1}$ of BW. The R20 showed the highest average levels (20.05 mg $kg^{-1}$ BW) compared to (< 0.011 mg $kg^{-1}$ BW) for most the rice samples. The EWI of Pb in the most rice samples was below the PTWI and the EWI of Cd in several imported rice samples were <0.011 mg $kg^{-1}$, this value was below the PTWI. Furthermore, the highest amount of EWI of Zn was observed in a R7 (213.3 mg$kg^{-1}$ BW). The lowest EWI was (45.54 mg $kg^{-1}$ BW) observed in R2. In comparison to the FAO/WHO set PTWI limit, the mean Zn contents for EWI were substantially high.

The highest EWI of Cr was observed in R33 (147.5 mg $kg^{-1}$ BW) and the lowest EWI was (0.00 mg $kg^{-1}$ BW) in R7. In addition, The EWI for Cr in nearly twenty one rice samples were lower than the PTWI limits. Furthermore, the high Cr content of may pose risks to human health. This might be as a result of the rice plant having a higher concentration of Cr due to the overuse of fertilizers to promote rice production (Guadie *et al.*, 2022). The R6 had the lowest EWI (59.29 mg $kg^{-1}$ BW), while R20 had the highest mean level of EWI for Fe (72838 mg $kg^{-1}$ BW). Unexpectedly, the PTWI set for Fe is missing. With regards to the Mn, The highest value was found in R12 (269.5 mg $kg^{-1}$ BW), while R2 had the lowest levels 8.306 mg $kg^{-1}$ BW. The EWI for Mn in imported rice brands was significantly higher than the PTWT.

The R13, R25, R27, and R29 had the lowest average EWI for Ni (0.011 mg $kg^{-1}$ BW), whereas the R33 had the highest average EWI for Ni (70.74 mg $kg^{-1}$ BW). For most brands, the EWI for Ni was higher than the PTWI set by (FAO/WHO, 2015). Additionally, R23 had the highest EWI value for Cu (82.49 mg $kg^{-1}$ BW), whereas R2 had the lowest (3.724 mg $kg^{-1}$ BW). The EWI for Cu was higher than the PTWI set by (FAO/WHO, 2015).

## 4. Conclusions

This research showed that the average values for Cu, Mn and Zn in imported rice grain samples were significantly above the acceptable FAO/WHO limits. The EWI for As and Cd was lower than the PTWI set by FAO/WHO. The EWI for Ni was higher than the PTWI for most brands except (R13, R25, R27, R29, R30, R31 and R32). In addition, the EWI for Cr in nearly twenty rice samples was below the PTWI limit. According to this, a high proportion of the weekly intake of Pb, Fe, Cu, Ni, Mn and Zn resulted from rice. Rice is the major diet consumed by Kurdistan population and is often eaten once or twice per day. Therefore, it is essential that the quality control organizations constantly assess and check the quantity of heavy metals in the imported rice. The potential health concerns associated with exposure to heavy metals from other imported food products into Kurdistan should also be taken into account.

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## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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**Table 1. Levels of heavy metals (As, Pb, Cd, Zn, Cr, Fe, Mn, Ni and Cu) in the imported rice types in (mg kg$^{-1}$) in Sulaymaniyah markets**

| Country of origin | Code of rice samples | As | Pb | Cd | Zn | Cr | Fe | Mn | Ni | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| Indian | R1 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D$^{****}$ | 5.125$^{p}$ | 12.15$^{b}$ | 110.5$^{k}$ | 3.150$^{y}$ | 5.925$^{b}$ | 1.075$^{p}$ |
| Indian | R2 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 3.975$^{rs}$ | < 0.001$^{l}$ | 7.175$^{pq}$ | 0.725$^{l}$ | 0.125$^{p}$ | 0.325$^{y}$ |
| Indian | R3 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 5.050$^{pq}$ | < 0.001$^{l}$ | 25.60$^{o}$ | 2.175$^{z}$ | 0.175$^{o}$ | 0.850$^{s}$ |
| Indian | R4 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 4.275$^{qrs}$ | < 0.001$^{l}$ | 53.38$^{m}$ | 1.525$^{\backslash}$ | 0.325$^{ij}$ | 0.875$^{rs}$ |
| Indian | R5 | < 0.001$^{a}$ | 0.150$^{g}$ | N.D | 5.000$^{pq}$ | < 0.001$^{l}$ | 53.13$^{m}$ | 1.700$^{l}$ | 0.225$^{mn}$ | 1.475$^{l}$ |
| Indian | R6 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 4.700$^{pqr}$ | < 0.001$^{l}$ | 5.175$^{q}$ | 2.175$^{z}$ | 0.275$^{kl}$ | 0.800$^{t}$ |
| Uruguay | R7 | < 0.001$^{a}$ | 0.075$^{h}$ | N.D | 18.63$^{a}$ | 0.000$^{l}$ | 809.8$^{g}$ | 7.925$^{g}$ | 0.350$^{i}$ | 0.900$^{r}$ |
| Uruguay | R8 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 8.450$^{ijklm}$ | < 0.001$^{l}$ | 835.3$^{f}$ | 7.925$^{g}$ | 0.200$^{no}$ | 5.500$^{c}$ |
| Uruguay | R9 | < 0.001$^{a}$ | 0.275$^{e}$ | N.D | 9.625$^{gh}$ | 0.775$^{f}$ | 1671$^{e}$ | 11.50$^{d}$ | 0.600$^{g}$ | 2.075$^{i}$ |
| Uruguay | R10 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 7.875$^{mno}$ | < 0.001$^{l}$ | 9.500$^{pq}$ | 6.000$^{i}$ | 0.300$^{jk}$ | 2.350$^{g}$ |
| Uruguay | R11 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 15.10$^{b}$ | 0.600$^{h}$ | 15.65$^{p}$ | 4.775$^{q}$ | 0.600$^{g}$ | 0.650$^{v}$ |
| Uruguay | R12 | < 0.001$^{a}$ | 1.700$^{b}$ | N.D | 9.600$^{gh}$ | 1.525$^{d}$ | 6233$^{b}$ | 23.53$^{a}$ | 1.000$^{d}$ | 0.700$^{u}$ |
| Turkey | R13 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 8.375$^{ijklmn}$ | < 0.001$^{l}$ | 26.38$^{o}$ | 5.100$^{p}$ | < 0.001$^{q}$ | 2.150$^{h}$ |
| Turkey | R14 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 9.775$^{fg}$ | < 0.001$^{l}$ | 29.03$^{no}$ | 4.450$^{s}$ | 0.050$^{q}$ | 0.550$^{w}$ |
| Kazakhstan | R15 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 9.200$^{ghij}$ | 0.475$^{i}$ | 37.50$^{n}$ | 3.650$^{x}$ | 0.275$^{kl}$ | 0.700$^{u}$ |
| Thailand | R16 | < 0.001$^{a}$ | 0.175$^{g}$ | N.D | 10.90$^{e}$ | 0.025$^{l}$ | 16.25$^{p}$ | 4.300$^{t}$ | 0.125$^{p}$ | 3.525$^{d}$ |
| Thailand | R17 | < 0.001$^{a}$ | 0.225$^{f}$ | N.D | 10.45$^{ef}$ | < 0.001$^{l}$ | 806.8$^{g}$ | 5.800$^{j}$ | 0.250$^{lm}$ | 2.800$^{e}$ |
| Thailand | R18 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 10.48$^{ef}$ | 0.200$^{k}$ | 12.60$^{pq}$ | 5.200$^{o}$ | 0.725$^{f}$ | 2.650$^{f}$ |
| Iran | R19 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 9.525$^{gh}$ | 1.050$^{e}$ | 431.5$^{h}$ | 8.200$^{f}$ | 0.525$^{h}$ | 2.000$^{j}$ |
| Iran | R20 | < 0.001$^{a}$ | 1.750$^{a}$ | N.D | 13.13$^{c}$ | 1.625$^{c}$ | 6358$^{a}$ | 22.33$^{b}$ | 1.375$^{c}$ | 6.600$^{b}$ |
| Pakistan | R21 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 12.30$^{d}$ | < 0.001$^{l}$ | 5.850$^{q}$ | 3.800$^{w}$ | 0.050$^{q}$ | 0.475$^{x}$ |
| Pakistan | R22 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 10.03$^{fg}$ | < 0.001$^{l}$ | 26.85$^{o}$ | 7.000$^{h}$ | 0.125$^{p}$ | 0.900$^{r}$ |
| America | R23 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 7.550$^{no}$ | < 0.001$^{l}$ | 69.88$^{l}$ | 6.000$^{i}$ | 0.300$^{jk}$ | 7.200$^{a}$ |
| America | R24 | < 0.001$^{a}$ | 0.525$^{c}$ | N.D | 8.325$^{klmn}$ | 0.725$^{g}$ | 4978$^{c}$ | 14.00$^{c}$ | 0.950$^{e}$ | 2.050$^{i}$ |
| Russian | R25 | < 0.001$^{a}$ | 0.175$^{g}$ | N.D | 7.675$^{mno}$ | < 0.001$^{l}$ | 10.53$^{pq}$ | 5.550$^{m}$ | < 0.001$^{q}$ | 1.150$^{o}$ |
| Russian | R26 | < 0.001$^{a}$ | 0.475$^{d}$ | N.D | 8.775$^{hijkl}$ | 0.300$^{j}$ | 1721$^{d}$ | 9.200$^{e}$ | 0.300$^{jk}$ | 1.225$^{n}$ |
| Russian | R27 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 7.325$^{o}$ | < 0.001$^{l}$ | 7.875$^{pq}$ | 5.625$^{l}$ | < 0.001$^{q}$ | 1.675$^{k}$ |
| Russian | R28 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 7.650$^{mno}$ | < 0.001$^{l}$ | 7.450$^{pq}$ | 5.800$^{j}$ | 0.125$^{p}$ | 1.425$^{m}$ |
| China | R29 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 8.900$^{hijk}$ | < 0.001$^{l}$ | 11.23$^{pq}$ | 4.250$^{u}$ | < 0.001$^{q}$ | 0.675$^{uv}$ |
| China | R30 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 9.250$^{ghi}$ | < 0.001$^{l}$ | 398.0$^{i}$ | 5.475$^{n}$ | 0.025$^{q}$ | 1.025$^{q}$ |
| China | R31 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 7.925$^{lmno}$ | < 0.001$^{l}$ | 14.35$^{pq}$ | 4.050$^{v}$ | 0.025$^{q}$ | 0.700$^{u}$ |
| China | R32 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 8.225$^{klmn}$ | < 0.001$^{l}$ | 30.55$^{no}$ | 4.600$^{r}$ | 0.025$^{q}$ | 0.450$^{x}$ |
| China | R33 | < 0.001$^{a}$ | < 0.001$^{i}$ | N.D | 8.275$^{klmn}$ | 12.88$^{a}$ | 149.3$^{j}$ | 5.725$^{k}$ | 6.175$^{a}$ | 1.025q |
| ***(FAO/WHO) standard limits.** | | **0.2** | **0.2** | **0.4** | ****Null** | *****1.0** | **#450** | **1.0** | **0.1** | ****Null** |

* From the Codex Alimentarius Commission (CAC) Standard Codex Stan 193-1995; amended in 2019. ** Null is zero value, *** CX/FAO/02/16, 2002, ****N. D not detected

#FAO/WHO Food Standards Program, vol. XVII, Codex Alimentariou, Geneva, Switzerland, 1st edition, 1984.

**Table 2. The calculated EWI values for the imported rice types (mg kg$^{-1}$ body weight).**

| Country of origin | Code of rice samples | Pb | Zn | Cr | Fe | Mn | Ni | Cu |
|---|---|---|---|---|---|---|---|---|
| Indian | R1 | < 0.011$^{i}$ | 58.72$^{p}$ | 139.2$^{b}$ | 1266$^{k}$ | 36.09$^{y}$ | 67.88$^{b}$ | 12.32$^{p}$ |
| Indian | R2 | < 0.011$^{i}$ | 45.54$^{rs}$ | < 0.011$^{l}$ | 82.21$^{pq}$ | 8.306$^{]}$ | 1.432$^{p}$ | 3.724$^{y}$ |
| Indian | R3 | < 0.011$^{i}$ | 57.86$^{pq}$ | < 0.011$^{l}$ | 293.3$^{o}$ | 24.91$^{z}$ | 2.005$^{o}$ | 9.739$^{s}$ |
| Indian | R4 | < 0.011$^{i}$ | 48.98$^{qrs}$ | < 0.011$^{l}$ | 611.5$^{m}$ | 17.472$^{\backslash}$ | 3.724$^{ij}$ | 10.03$^{rs}$ |
| Indian | R5 | 1.719$^{g}$ | 57.289$^{pq}$ | < 0.011$^{l}$ | 608.7$^{m}$ | 19.477$^{[}$ | 2.578$^{mn}$ | 16.89$^{l}$ |
| Indian | R6 | < 0.011$^{i}$ | 53.85$^{pqr}$ | < 0.011$^{l}$ | 59.29$^{q}$ | 24.92$^{z}$ | 3.151$^{kl}$ | 9.166$^{t}$ |
| Uruguay | R7 | 0.859$^{h}$ | 213.3$^{a}$ | 0.000$^{l}$ | 9277$^{g}$ | 90.79$^{g}$ | 4.010$^{i}$ | 10.31$^{r}$ |
| Uruguay | R8 | < 0.011$^{i}$ | 96.81$^{ijklm}$ | < 0.011$^{l}$ | 9570$^{f}$ | 90.79$^{g}$ | 2.291$^{no}$ | 63.01$^{c}$ |
| Uruguay | R9 | 3.151$^{e}$ | 110.8$^{gh}$ | 8.879$^{f}$ | 19142$^{e}$ | 131.7$^{d}$ | 6.874$^{g}$ | 23.77$^{i}$ |
| Uruguay | R10 | < 0.011$^{i}$ | 90.23$^{mno}$ | < 0.011$^{l}$ | 108.8$^{pq}$ | 68.74$^{i}$ | 3.437$^{jk}$ | 26.92$^{g}$ |
| Uruguay | R11 | < 0.011$^{i}$ | 173.0$^{b}$ | 6.874$^{h}$ | 179.3$^{p}$ | 54.70$^{q}$ | 6.874$^{g}$ | 7.447$^{v}$ |
| Uruguay | R12 | 19.48$^{b}$ | 109.9$^{gh}$ | 17.47$^{d}$ | 71406$^{b}$ | 269.5$^{a}$ | 11.45$^{d}$ | 8.020$^{u}$ |
| Turkey | R13 | < 0.011$^{i}$ | 95.95$^{ijklmn}$ | < 0.011$^{l}$ | 302.2$^{o}$ | 58.43$^{p}$ | < 0.011$^{q}$ | 24.63$^{h}$ |
| Turkey | R14 | < 0.011$^{i}$ | 111.9$^{fg}$ | < 0.011$^{l}$ | 332.5$^{no}$ | 50.98$^{s}$ | 0.573$^{q}$ | 6.301$^{w}$ |
| Kazakhstan | R15 | < 0.011$^{i}$ | 105.4$^{ghij}$ | 5.442$^{i}$ | 429.6$^{n}$ | 41.81$^{x}$ | 3.151$^{kl}$ | 8.020$^{u}$ |
| Thailand | R16 | 2.005$^{g}$ | 124.9$^{e}$ | 0.286$^{l}$ | 186.2$^{p}$ | 49.26$^{t}$ | 1.432$^{p}$ | 40.38$^{d}$ |
| Thailand | R17 | 2.578$^{f}$ | 119.7$^{ef}$ | < 0.011$^{l}$ | 9243$^{g}$ | 66.45$^{j}$ | 2.864$^{lm}$ | 32.08$^{e}$ |
| Thailand | R18 | < 0.011$^{i}$ | 120.0$^{ef}$ | 2.291$^{k}$ | 144.4$^{pq}$ | 59.57$^{o}$ | 8.306$^{f}$ | 30.36$^{f}$ |
| Iran | R19 | < 0.011$^{i}$ | 109.1$^{gh}$ | 12.03$^{e}$ | 4943$^{h}$ | 93.94$^{f}$ | 6.015$^{h}$ | 22.91$^{j}$ |
| Iran | R20 | 20.05$^{a}$ | 150.8$^{c}$ | 18.61$^{c}$ | 72838$^{a}$ | 255.7$^{b}$ | 15.75$^{c}$ | 75.62$^{b}$ |
| Pakistan | R21 | < 0.011$^{i}$ | 140.9$^{d}$ | < 0.011$^{l}$ | 67.02$^{q}$ | 43.53$^{w}$ | 0.573$^{q}$ | 5.442$^{x}$ |
| Pakistan | R22 | < 0.011$^{i}$ | 114.8$^{fg}$ | < 0.011$^{l}$ | 307.6$^{o}$ | 80.20$^{h}$ | 1.432$^{p}$ | 10.31$^{r}$ |
| America | R23 | < 0.011$^{i}$ | 86.50$^{no}$ | < 0.011$^{l}$ | 800.6$^{l}$ | 68.74$^{i}$ | 3.437$^{jk}$ | 82.49$^{a}$ |
| America | R24 | 6.015$^{c}$ | 95.38$^{klmn}$ | 8.306$^{g}$ | 57027$^{c}$ | 160.4$^{c}$ | 10.88$^{e}$ | 23.48$^{i}$ |
| Russian | R25 | 2.005$^{g}$ | 87.93$^{mno}$ | < 0.011$^{l}$ | 120.5$^{pq}$ | 63.58$^{m}$ | < 0.011$^{q}$ | 13.17$^{o}$ |
| Russian | R26 | 5.442$^{d}$ | 100.5$^{hijkl}$ | 3.437$^{j}$ | 19712$^{d}$ | 105.4$^{e}$ | 3.437$^{jk}$ | 14.03$^{n}$ |
| Russian | R27 | < 0.011$^{i}$ | 83.92$^{o}$ | < 0.011$^{l}$ | 90.22$^{pq}$ | 64.44$^{l}$ | < 0.011$^{q}$ | 19.19$^{k}$ |
| Russian | R28 | < 0.011$^{i}$ | 87.65$^{mno}$ | < 0.011$^{l}$ | 85.35$^{pq}$ | 66.45$^{j}$ | 1.432$^{p}$ | 16.32$^{m}$ |
| China | R29 | < 0.011$^{i}$ | 101.9$^{hijk}$ | < 0.011$^{l}$ | 128.6$^{pq}$ | 48.69$^{u}$ | < 0.011$^{q}$ | 7.734$^{uv}$ |
| China | R30 | < 0.011$^{i}$ | 105.9$^{ghi}$ | < 0.011$^{l}$ | 4559$^{i}$ | 62.72$^{n}$ | 0.286$^{q}$ | 11.74$^{q}$ |
| China | R31 | < 0.011$^{i}$ | 90.79$^{lmno}$ | < 0.011$^{l}$ | 164.4$^{pq}$ | 46.40$^{v}$ | 0.286$^{q}$ | 8.020$^{u}$ |
| China | R32 | < 0.011$^{i}$ | 94.24$^{klmn}$ | < 0.011$^{l}$ | 350.1$^{no}$ | 52.70$^{r}$ | 0.286$^{q}$ | 5.156$^{x}$ |
| China | R33 | < 0.011$^{i}$ | 94.81$^{klmn}$ | 147.5$^{a}$ | 1710$^{j}$ | 65.59$^{k}$ | 70.74$^{a}$ | 11.74$^{q}$ |
| ****PTWI (mg-kg$^{-1}$ body weight)** | | **0.025** | **0.42** | **0.023** | **Ns*** | **0.11** | **0.035** | **0.5** |

*Different Letters inside the column displays significant differences among the treatment means at (P ≤0.05) according to Duncan's test.

* There is no PTWI set for Iron, **PTWI stated in (FAO/WHO, 2015)