Occurrence of microorganisms, aflatoxin, ochratoxin, and heavy metals in paddy and rice produced in Iraq

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ABSTRACT

To determine the effect of houseware cleanliness and mill procedure on the contamination level of paddy and its produced rice, paddy and rice samples of seven different mills in three provinces of Iraq were investigated for microorganisms, mycotoxins, and heavy metals. Paddy and rice samples of each mill were gathered during the mills' operation to determine the effect of mill processing on the contamination level. The result showed that all paddy and rice samples were within the acceptable limit regarding total plate count (TPC) with range 4.8×10^3 to 5.6×10^5 cfu/g of paddy and 6.0×10^2 to 2.1×10^5 cfu/g for rice. Some paddy samples exceeded the FDA limit of molds and yeast such as mills in Babel and Alnajaf provinces with 1.7×10^4 and 3.5×10^4 cfu/g respectively. Paddy samples of the same mentioned mills had total coliform count more than the FDA limit (1.0×10^4 cfu/g), while all rice samples had less than the FDA limit, however, some rice samples exceeded Iraqi limit (1.0×10^3 cfu/g). *E. coli* bacteria has been detected in paddy samples of the same two mills, and the count was within the FDA limit. For rice samples, *E. coli* was less than 3 cell/g, which was the detection limit of the conducted method. Some paddy and rice samples overpassed the authorized limit (CEC and IQS) of total aflatoxin (AFTs) with range between 1.4 to 10.2 µg/kg for paddy samples and 1.1 to 8.8 µg/kg for rice samples. Most samples overpassed ochratoxin A (OTA) limit (CEC), which was 5 µg/kg for paddy and 3 µg/kg for rice. Cadmium concentration was within the limit approved by CAC and IQS, while most samples overpassed lead (Pb) concentration. In conclusion, the mill processing reduced microorganisms count, while it had no clear effect on the mycotoxin reduction and heavy metals concentration. Enhancing the safety of the produced rice in Iraq should be considered in the next planning.

Keywords: Rice safety, mycotoxins, cadmium, lead, *E. coli*.

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INTRODUCTION

Rice (*Oryza sativa* L) is one of the most consumed grains after wheat worldwide. China and India were the most producers of milled rice in 2018/2019 with 148.5 and 116.4 million tons respectively (Shahbandeh, 2020). Seventy–five percent of the daily taken calories were from rice for Asian people (Ghadge and Prasad, 2012). In Iraq, the consumed rice is either imported or domestic, the domestic rice is cultivated in three main provinces, which are Alnajaf, Aldiwania, and Babel, and there are two main varieties, which are Anber and Yassamine (known internationally as Jasmine). The production quantity of 2015, 2016, and 2017 were 200, 43, and 100 thousand tons respectively, and Yassamine rice presented 97%, 99%, and 78% respectively (Alhendi *et al*., 2019).

Food microbiological assessment is often a mandatory step in the food production chain because of the negative effect of microbial contamination on foodstuff (Falasconi *et al*., 2012). Plants might be a source for human pathogens, such as *E. coli* and *Salmonella* spp. (Franz and Van Bruggen, 2008). Several outbreaks have been reported because of Salmonellosis and *E. coli O*157: H7 in the plant. The contamination is probably because of fields or the packaging step (Beuchat, 1999; Barak and Liang, 2008). Such outbreaks were previously related to animal products regularly. Microorganisms can grow on grains and final products if the storage conditions were not proper (Aydin *et al*., 2009). In addition to the direct effect of microorganisms' growth on the deterioration of foodstuffs, some microbes, such as fungi can produce mycotoxin, which is secondary metabolites. Mycotoxins are serious problems for human and animal health (Eslami *et al*., 2015). Mycotoxin occurs in a wide range of food commodities, they contaminate plant products including dried fruit, oilseed, nut and cereals (corn, wheat, rice, etc.). Therefore, setting a maximum level of mycotoxin in food helps countries to reduce the threat of mycotoxin (Karlovsky *et al*., 2016). Aflatoxins are the most important and dangerous mycotoxin, and they are produced by *Aspergillus flavus* and *Aspergillus parasiticus* (Park *et al*., 2005). Chronic exposures to aflatoxin lead to developing liver cancer (Bansal *et al*., 2011). Ochratoxin A is another type of mycotoxin produced by specific species of *Aspergillus* spp. and *Penicillium* spp., and it is the most toxic of the ochratoxin types (Duarte *et al*., 2010). Ochratoxin A has been identified as carcinogenic, immunotoxic, nephrotoxic and hepatoxic, and it has been found in foodstuffs including grains (Bansal *et al*., 2011).

Heavy metals are not biodegradable materials and accumulating in different organs of the human body, therefore, they are considered for human health. Plants are exposed to heavy metals either from contaminated soils, polluted air, and/or contaminated irrigation water (Elbagermi *et al*., 2012). Soils or air are contaminated by heavy metals (lead and cadmium) via emissions produced in different ways such as burning transportation fuel (Järup, 2003). Heavy metals have various effects on human and animal health. For example, lead poisoning can cause neurodevelopmental effects, hypertension, mortality, impaired fertility, impaired renal function, adverse pregnancy outcomes besides a headache, abdominal pain and irritability. While cadmium probably causes kidney damage, and it is considered as a carcinogenic metal (Järup, 2003).

Imported rice in Iraq is routinely inspected for microorganisms, total aflatoxin and heavy metals (Pb and Cd) via the Grain Board of Iraq (GBI). Conversely, for the domestic cultivated rice, most of these assessments have not been conducted during receiving paddy from farmers or after rice processing in several mills. Therefore, this study aims to investigate the microorganisms count, mycotoxins level, and heavy metals concentration of paddy of several mills in three provinces of Iraq and the produced rice to study the effect of rice processing on the contamination level. In addition to evaluating the safety of paddy and rice compared with the national and international standard limits.

MATERIALS AND METHODS

Samples Collections

Paddy and rice samples were collected from seven different mills before processing and after processing (final product) respectively in three different provinces (Alnajaf, Aldiwania and Babel) during the 2018 process season. Three independent paddy and rice samples of each mill were grabbed from the storehouse of paddy and rice production lines, and each sample was about 3 kg. The samples were taken to Baghdad where the Quality Control Department (QCD) is to be analyzed for microorganisms, mycotoxins (i.e., aflatoxin (AFTs) and ochratoxin A (OTA)) and heavy metals. The samples have been collected at two different times depending on the mill's work. The first two samples were taken from two governmental mills during January and the other five samples were taken from private mills during June. Sterilized tools and gloves were used during gathering samples to prevent microorganism's contamination. Generally, the first two mills were cleaner than other mills.

They have silos to store paddy, and the paddy was transferred to mills by conveyors, while the paddy of the other mills was stored in a warehouse and the paddy transferred to mills by carrying cars. The total number of samples was 21 paddy samples and 21 rice samples from seven mills.

Microbiological Analyses

Twenty-five grams of paddy or rice samples were used for microbiological analyses. Nutrient agar was used for total plate count (TPC), sabouraud dextrose agar was used for yeast and molds count, and violet red bile agar was used for total coliform. *E. coli* detection was based on the 3–tubes MPN (Aydin *et al*., 2009), and the positives tubes were streaked on L–EMB agar. Lastly, biochemical tests (IMVIC) were done for colonies with metallic green to confirm *E. coli* bacteria. The detection limit was 3 bacteria per gram. All microbiological analyses were made at the microbiological laboratory, QCD and GBI, and were accomplished in triplicate.

Mycotoxins

Paddy or rice samples were grounded by a Brabender mill (Brabender® OHG, Duisburg, Germany) to produce paddy and rice meals that used in mycotoxin and heavy metals analyses. The quantitative analysis of total AFTs (B1, B2, G1 and G2) and OTA were performed based on a direct competitive ELISA using Veratox quantitative test (Neogen, product # 8030, Lansing, MI, USA) for AFTs and Veratox quantitative test (Neogen, product #8610, Lansing, MI, USA) for OTA by adding 25 mL of 70% methanol to 5 gm of ground sample and shook vigorously for 3 min in a mechanical shaker. The test procedure was followed, and the intensity of the produced color was measured by ELISA plate reader (ELx50, Biotek Instrument, Inc, Highland Park, Winooski, USA) at 650 µm. A standard curve of AFT (0, 5, 15 and 50 ppb) and of OTA (0, 2, 5, 10 and 25) were used to determine the total AFT and OTA concentrations respectively. All mycotoxin analyses were made at the chemical laboratory, QCD and GBI, and were measured in duplicates.

Heavy Metals

Heavy metals (Cd and Pb) were detected by using the Atomic Absorption Spectrophotometer (AAS; AA−7000 Atomic Absorption Spectrophotometer, Shimadzu, Japan) as described in detail in the Alhendi and Al–Mayali (2018) study. In brief, ten grams of a ground meal of paddy or rice was burned for 6 h at 600°C and after cooling, 5 ml of HCl (6 M) were added, and the samples were evaporated on a hot plate. The residues were dissolved to 20 ml with 0.1 M HNO_3 before reading by AAS (Jorhem, 2000). Heavy metals analyses were done at the chemical laboratory, QCD and GBI, and were measured in triplicate.

Statistical Analysis

One-way analysis of variance (ANOVA) was performed for statistical analysis of all the paddy and rice data of each category simultaneously. Least Significant Difference (LSD) of means was implemented by using SAS version 9.0 (Cary, NC, USA). Significant differences were considered at $\alpha = 0.05$ level.

RESULTS AND DISCUSSIONS

Table 1 shows the microbiological group enumerations of paddy and rice taken from seven mills in Iraq. For TPC bacteria, all the paddy and rice samples were within the acceptable limit of FDA regulation limits (10^6 cfu/g). The highest TPC number was found in paddy samples, which was 5.6×10^5 cfu/g taken from Babel mill followed by another paddy sample taken from Alnajaf mill and rice sample obtained from Babel mill with 2.1×10^5 cfu/g. Regarding molds and yeast count, all the rice samples were within the acceptable limit (10^4 cfu/g), while some paddy samples, the first two mills, overpassed the acceptable FDA limits, with 1.7×10^4 and 3.5×10^4 cfu/g respectively (Table 1). The total coliform count of some rice samples was overpassed the acceptable Iraqi limit, and just the first two paddy samples overpassed FDA limit. *E. coli* bacteria has been found in the paddy samples of the first two mills and the count has been within FDA limit (Table 1). For all the tested samples, paddy samples have more microorganisms than counterpart rice samples, and the result highlights the effect of paddy processing on decreasing the microorganisms count. The rice production system in Iraq briefly consists of a clean section (sieves) and two huller machines. The first huller machine removed the husk of paddy, and the second machine removed the thin layer of the dehulled rice to obtain the required whitening, which must be more than 32. Although the paddy and rice of the first two mills stored in better conditions compared to other mills, the microbial count was higher than other mills. The reason behind high microbial count is probably because of the time of samples gathering of these two mills, which was in January compared to samples gathering of the others (June). The former one was close to the harvest season time, and probably paddy had a more microbial count from fields or it might be because of high moisture content of paddy at this time of year compared to June. June in Iraq is hot that led to reducing moisture content meaningfully and consequently reduces the microbial count. Overpassed the acceptable level of molds and yeast, and total coliform is not in agreement with the Alhendi and Mohammed (2018) study, which was on wheat cultivated in several provinces of Iraq, and all the microorganism's groups were within the acceptable level. The acceptable levels of molds and yeast in their study were 10^4 and 10^5 cfu/g for FDA and Quality Standard of Iraq respectively, and for total coliform was 10^4 cfu/g for FDA.

Microbiological limit of rice approved by FDA was reported to be of each 5 samples two of them should be within the acceptable limit, which is 10^6, 10^4, 10^4 cfu/g and 10^4 MPN/g for TPC, yeast and molds, total coliform, and *E. coli* respectively, and the other three samples should be within the good limit (10^2 cfu/g) mentioned in Table 1 for all categories. Table 2 expresses sample number that overpassed the good limit to the total sample number measured for each mill. All paddy samples and most rice samples exceeded the FDA good limit for TPC. This result agrees with what Alhendi and Mohammed (2018) mentioned, which most wheat samples taken from several Iraqi provinces overpassed the good limit for TPC. Although most paddy samples and all rice samples were within the acceptable limit for molds and yeast (Table 1), all the paddy samples and some of the rice samples exceeded the good limit (10^2 cfu/g). Therefore, samples were overpassed the authorized limit for human consumption. The result of the total coliform for paddy and rice samples were almost similar to the molds and yeast results. In comparison, there were no wheat samples passed the sample–limit number of good qualities for total coliform (Alhendi and Mohammed, 2018). All paddy and rice samples were within the good quality approved by FDA for *E. coil* count (Table 2), while there was no good and acceptable quality in IQS for *E. coli*. All rice samples should have zero *E. coli* in one-gram tested rice (IQS, 2006).

Table 1 Microbiological enumeration of paddy and rice from several mills in three different provinces of Iraqi

Mills	Total plate count (cfu/g)		Molds and yeast (cfu/g)		Total coliform (cfu/g)		*E. coli* (cell/g)	
	Paddy	Rice	Paddy	Rice	Paddy	Rice	Paddy	Rice
1 Babel	5.6×10^5 $(2.3\times10^5)^a$	2.1×10^5 $(3.1\times10^5)^b$	1.7×10^4 $(2.1\times10^4)^{a*}$	1.0×10^1 $(0.0\times10^1)^a$	3.8×10^4 $(3.2\times10^4)^{ab*}$	1.5×10^3 $(1.8\times10^3)^{b**}$	19.0 (5.7)	< 3
2 Alnajaf	2.1×10^5 $(1.1\times10^5)^b$	6.0×10^2 $(7.9\times10^2)^b$	3.5×10^4 $(1.1\times10^4)^{a*}$	8.8×10^1 $(6.4\times10^1)^a$	1.2×10^5 $(1.7\times10^5)^{a*}$	4.2×10^2 $(5.6\times10^2)^b$	3.6 (0.0)	< 3
3 Alnajaf	4.8×10^3 $(7.4\times10^3)^b$	8.8×10^2 $(6.8\times10^2)^b$	4.1×10^3 $(5.0\times10^3)^a$	1.6×10^2 $(5.7\times10^1)^a$	4.6×10^2 $(4.9\times10^2)^b$	9.6×10^1 $(1.2\times10^2)^b$	< 3	< 3
4 Alnajaf	2.0×10^5 $(1.0\times10^3)^b$	3.5×10^2 $(4.3\times10^2)^b$	1.2×10^3 $(8.2\times10^2)^a$	2.3×10^2 $(5.7\times10^1)^a$	1.5×10^3 $(1.2\times10^3)^b$	1.0×10^3 $(1.1\times10^3)^{b**}$	< 3	< 3
5 Alnajaf	2.8×10^4 $(2.0\times10^4)^b$	1.1×10^3 $(1.0\times10^3)^b$	2.1×10^3 $(1.2\times10^3)^a$	< 10	9.3×10^2 $(1.1\times10^3)^b$	$\leq 10^b$	< 3	< 3
6 Aldiwania	9.1×10^3 $(8.3\times10^3)^b$	3.1×10^3 $(2.1\times10^3)^b$	1.4×10^3 $(5.3\times10^2)^a$	< 10	1.2×10^3 $(1.5\times10^3)^b$	1.2×10^3 $(1.6\times10^3)^{b**}$	< 3	< 3
7 Aldiwania	8.2×10^4 $(1.1\times10^5)^b$	1.0×10^2 (0.0)	4.3×10^3 $(2.7\times10^3)^a$	< 10	1.1×10^3 $(1.8\times10^3)^b$	7.6×10^2 $(7.8\times10^2)^b$	< 3	< 3
IQS: Good and accepted Q	–		10^2 to 10^4		10^2 to 10^3		–	Zero
FDA: Good and accepted Q	10^2 to 10^6		10^2 to 10^4		10^2 to 10^4		10^2 to 10^4	

Note: Values are expressed as a mean (SD). Means with different letters within the same category are significantly different at $P < 0.05$. IQS = Iraqi Quality Standardization (2006), FDA = Food and Drug Administration Circular (2013), * overpassed FDA acceptable limit, ** overpassed IQS acceptable limit

Table 2 Numbers of samples had more than the good quality limit to a total number of samples taken from a mill

Mills	Total plate count		Mold and yeast		Total coliform		*E. coli*	
	Paddy	Rice	Paddy	Rice	Paddy	Rice	Paddy	Rice
1 Babel	3 of 3*	3 of 3*	3 of 3*	0 of 3	3 of 3*	3 of 3*	0 of 3	0 of 3
2 Alnajaf	3 of 3*	3 of 3*	3 of 3*	1 of 3	3 of 3*	2 of 3**	0 of 3	0 of 3
3 Alnajaf	3 of 3*	3 of 3*	2 of 3**	3 of 3*	3 of 3*	1 of 3	0 of 3	0 of 3
4 Alnajaf	3 of 3*	1 of 3	3 of 3*	3 of 3*	3 of 3*	3 of 3*	0 of 3	0 of 3
5 Alnajaf	3 of 3*	2 of 3**	3 of 3*	0 of 3	2 of 3**	0 of 3	0 of 3	0 of 3
6 Aldiwania	3 of 3*	3 of 3*	3 of 3*	0 of 3	3 of 3*	3 of 3*	0 of 3	0 of 3
7 Aldiwania	3 of 3*	1 of 3	3 of 3*	0 of 3	2 of 3**	2 of 3**	0 of 3	0 of 3
Iraqi limit	–	–	–	2 of 5	–	2 of 5	–	–
FDA limit	2 of 5		2 of 5		2 of 5		2 of 5	

Note: FDA = Food and Drug Administration Circular, * samples with higher than the maximum allowable number of marginally acceptable samples number, ** samples with high possibility of having higher than the maximum allowable number of marginally acceptable samples number

Molds cause human illness through three mechanisms, which are direct infection by molds, negative effect on the immune system and toxic effect from their byproducts (Falasconi *et al*., 2012). Mycotoxins are the main destructive byproducts of molds for humans, animals and crops (Zain, 2011). Aflatoxins are the most dangerous of all mycotoxins, and AFT B1 is the most dangerous of aflatoxins groups, therefore a limit of total aflatoxin and in some countries a limit of AFT B1 were determined (CAC, 2016). Although aflatoxin of rice is low and varies from country to country, the high consumed amount of rice and the harmful effect of aflatoxin make the low level concern (Elzupir *et al*., 2017). Table 3 shows total AFTs and OTA for paddy and rice in several mills. Four rice samples (mill # 3, 5, 6 and 7) overpassed CEC limit (4 μg/kg), and several paddy samples overpassed CEC limit (Table 3). Most paddy samples had total AFTs more than rice samples for the same mill. Pinotti *et al*. (2016) mentioned that mycotoxin quantity is affected by food processing, for example in cereal processing, mycotoxin is more concentrated in the removal parts that are usually used for animal feed. However, the result of this study confirmed that some rice samples had more AFTs than paddy samples (Table 3), which is probably because of rice and paddy samples have been taken from industry mills, which not all taken rice samples produced from the same paddy samples. The confirmed result of the Pinotti *et al*. (2016) study was usually made on a laboratory mill, which was the same paddy samples used to produce rice samples. The range of AFTs for rice samples of this study was between 1.1 to 8.8 μg/kg, which is within the range of the Lai *et al*. (2015) study, which was between 0.03 to 21 μg/kg for 370 rice samples taken from six different provinces in China. In addition, Eslami *et al*. (2015) mentioned that the range of AFTs in rice samples taken from Korea, Iran, and Pakistan was between 2.1 to 7.7, 0.1 to 10, and not reported to 68.3 μg/kg, respectively. Although there is no limit of rice in IQS, the imported rice contract stated that total AFTs must not be exceeded 5 μg/kg.

Table 3 explains the OTA level in paddy and rice samples taken from seven mills, and the range was between 4.2 to 11.6 and 5.1 to 12.7 μg/kg for paddy and rice samples respectively. Most paddy and rice samples overpassed the limit approved by CEC. Although most rice samples had OTA more than paddy samples, the increment was not significantly different. Lai *et al*. (2015) reported that OTA range was between 0.03 to 3.2 μg/kg for 370 rice samples taken from six different provinces in China, which is less than the range of the current study. Also, Feizy *et al*. (2011) mentioned that the range of OTA was between 0.2 to 4.8 for 182 samples in Iran. Therefore, the samples of this study had OTA more than the amount reported by previous studies, and this is probably because of the different environments of produced rice, such as the used seed, irrigated water, soil types, processing method, etc. Also, the difference could be because of the determined method, which was HPLC method for the two mentioned studies, while in this study ELISA method was used, and the antibody cross-reactivity of the used kit was 18% sensitive for ochratoxin B in addition to 100% sensitivity for OTA.

Table 3 Total aflatoxins and ochratoxin A in paddy and the produced rice of several mills

Mills	Aflatoxins (μg/kg)		Ochratoxin A (μg/kg)	
	Paddy	Rice	Paddy	Rice
1 Babel	2.2 (0.1)	1.1 (0.2)	4.6 (0.3)	6.6 (1.9)*
2 Alnajaf	3.6 (1.3)	1.7 (0.6)	4.3 (1.8)	5.7 (2.3)*
3 Alnajaf	1.4 (1.0)	5.0 (2.1)*	5.1 (1.1)*	8.7 (4.0)*
4 Alnajaf	3.3 (1.1)	2.4 (0.7)	5.9 (1.8)*	8.3 (2.7)*
5 Alnajaf	5.7 (3.2)*	4.2 (1.2)*	4.2 (0.9)	5.1 (1.6)*
6 Aldiwania	3.1 (0.7)	8.8 (1.4)*	–	12.7 (2.8)*
7 Aldiwania	10.2 (6.7)*	6.0 (4.7)*	11.6 (0.8)*	9.5 (1.8)*
IQS	–	–	–	–
CEC	4	4	5	3

Note: Values are expressed as a mean (SD). IQS = Iraqi Quality Standardization (2006), CEC = Commission of the European Communities (2006), * overpassed CEC limit

Cadmium is a health hazardous substance that can be easily taken up from crops, such as rice, wheat, vegetable, etc. It can be taken from food, which causes kidney damage or kidney and lung damage if taken from occupation (Åkesson *et al*., 2014). Therefore, the Cd accumulation in a food chain is considered as a major environmental issue worldwide (Li *et al*., 2017). Table 4 presents the concentrations of Cd and Pb in the paddy and rice samples. All rice and paddy samples were within Cd limit approved by IQS and CAC. There was no significant difference between paddy and counterparts rice except for samples of mill # 1 that paddy samples had a higher Cd amount. Cadmium range of rice determined by Cao *et al*. (2010) in China was between 0.005 to 0.032 mg/kg, which is lower than the range of the current study (0.055 to 0.066 mg/kg). Alhendi and Al–Mayali (2018) mentioned that Cd range of wheat cultivated in several provinces of Iraq was 0.002 to 0.035 mg/kg, which is also lower than the current range. The reason behind this result is probably because planted rice is soaked in water for a long time compared to other plants. On the other side, the Cd concentration of rice consumed in Iran was higher than the limit approved by CAC, and approximately 65% of consumed Cd is from rice (Naseri *et al*., 2015).

Exposure to heavy metals such as Cd, Pb and arsenic (As) can cause cancer in humans (Fakhri *et al*., 2018). A human can be exposed to Pb from several resources such as food cans, paints, different kinds of pipes and gasoline (Batool *et al*., 2017). Grandjean and Landrigan (2014) mentioned that Pb can cause chronic diseases such as developmental neurotoxicants. Table 4 shows Pb concentration in paddy and rice samples taken from several mills. Most paddy and rice samples overpassed the authorized limit. Cao *et al*. (2010) reported that the Pb range was 0.0076 to 0.12 mg/kg in China, which is lower than the CAC limit. Norton *et al*. (2014) stated that Pb was determined in several countries such as USA (162 samples), France (24 samples), Japan (20 samples), Pakistan (14 samples), etc., and all the tested samples had Pb less than 0.02 mg/kg, which is ten times lower than the CAC limit. Alhendi and Al-Mayali (2018) reported that Pb concentration in the wheat cultivated in Iraq was between not determined to 0.19 mg/kg, which is lower than the authorized limited and lower than Pb concentration of baddy and rice samples of this study.

Table 4 Heavy metal concentration of Cd and Pb of paddy and produced rice from several mills in Iraq

Mills	Cd (mg/kg)		Pb (mg/kg)	
	Paddy	Rice	Paddy	Rice
1 Alnajaf	0.060 (0.001)^{bc}	0.055 (0.003)^{d}	0.097 (0.024)^{f}	0.093 (0.024)^{f}
2 Alnajaf	0.064 (0.001)^{ab}	0.061 (0.001)^{bc}	0.236 (0.068)^{cd*}	0.124 (0.006)^{df}
3 Alnajaf	0.059 (0.002)^{bcd}	0.057 (0.001)^{cd}	0.525 (0.008)^{a*}	0.339 (0.014)^{bc*}
4 Aldiwania	0.055 (0.002)^{cd}	0.056 (0.002)^{cd}	0.363 (0.026)^{b*}	0.318 (0.032)^{bc*}
5 Aldiwania	0.066 (0.000)^{a}	0.066 (0.001)^{a}	0.289 (0.040)^{bc*}	0.313 (0.019)^{bc*}
IQS	–	0.4	–	0.2
CAC	0.4	0.4	0.2	0.2

Note: Values are expressed as a mean (SD). Means with different letters within the same category are significantly different at P < 0.05. IQS = Iraqi Quality Standardization (2006), CAC = Codex Alimentarius Commission (2016), * Overpassed the authorized limit

Because the amount of the produced rice in Iraq is limited, the Iraq government usually imports rice and never or rarely exports it. However, such an investigation is important in terms of giving an indication of the safety of the paddy and the produced rice. Comparing the number of contaminations of paddy and rice at the same mills indicates the actual effect of rice processing on reducing the contamination. A one-year investigation is inadequate to determine or confirm the safety of a product. Therefore, more investigations are required. Also, determining the source of the contamination either irrigated water, soil, etc. is an important step to solve the problem and enhance rice safety in Iraq.

CONCLUSIONS

In this work, microorganisms, mycotoxins, and heavy metals of paddy and rice processed in several mills of Iraq were measured. Rice processing reduced microorganisms count, while it had no exact effect on mycotoxins and heavy metals. Most paddy and rice samples had total coliform, molds and yeast, AFTs, OTA, and Pb more than the authorized limit. While samples were safe in terms of *E. coli* count and Cd concentration, therefore, decreasing the level of microorganisms, mycotoxin, and Pb should be encouraged and considered in the next planning.

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