Journal of Food Protection, Vol. 85, No. 6, 2022, Pages 938–944
https://doi.org/10.4315/JFP-21-434

Research Paper

Aflatoxin B1 in Rice: Effects of Storage Duration, Grain Type and Size, Production Site, and Season

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MS 21-434: Received 2 December 2021/Accepted 4 February 2022/Published Online 10 February 2022

ABSTRACT

Our study evaluated aflatoxin B1 (AFB1) levels in packed rice marketed in Lebanon and determined the exposure to this toxin from rice consumption. A total of 105 packed white, parboiled, and brown rice bags were collected. Enzyme-linked immunosorbent assay was used to measure AFB1. A comprehensive food frequency questionnaire was completed by 500 participants to determine patterns of rice consumption and, subsequently, the exposure levels to AFB1 from rice consumption in Lebanon. AFB1 was detected in all rice samples (100%). The average concentration ± standard deviation of AFB1 was 0.5 ± 0.3 μg/kg. Contamination ranged between 0.06 and 2.08 μg/kg. Moisture content in all rice samples was below the recommended percentage (14%). Only 1% of the samples had an AFB1 level above the European Union limit (2 μg/kg). Brown rice had a significantly higher AFB1 level than white and parboiled rice ($P = 0.02$), while a significant difference was found between both collections for the same brands ($P = 0.016$). Packing season, packing country, country of origin, presence of a food safety management certification, grain size, and time between packing and purchasing had no significant effect. Exposure to AFB1 from rice consumption in Lebanon was calculated as 0.1 to 2 ng/kg of body weight per day.

HIGHLIGHTS

- Mean concentration of AFB1 was 0.5 μg/kg, and contamination was 0.06 to 2.08 μg/kg.
- AFB1 was detected in all rice samples, and 1% only had an AFB1 level above the EU limit.
- Brown rice had a significantly higher AFB1 level than white and parboiled rice.
- A significant difference was found between both collections for the same brands.

Key words: Aflatoxin B1, Contamination; Dietary intake; Enzyme-linked immunosorbent assay; Rice

Mycotoxins are toxic secondary metabolites that have chemical and thermal stability and a small molecular weight. They are produced by fungi such as *Aspergillus, Penicillium, Alternaria, Fusarium,* and *Claviceps (47)*. The number of reported mycotoxins exceeds 400; however, the most significant family in terms of food safety and economic assessment are aflatoxins (AFs). Several crops, such as cereals, nuts, forages, fruits, vegetables, and their by-products, are at high risk of contamination with mycotoxins, in addition to animal products, when the consumed animal feeds are contaminated with the toxins *(39)*. The Food and Agriculture Organization reported that mycotoxins can contaminate around 25% of food crops worldwide *(12)*. Moreover, the Rapid Alert System for Food and Feed of the European Union (EU) ranks mycotoxins in the second position when identifying the total number of hazard notifications *(32)*. Incorrect agricultural and harvesting steps, erroneous drying, handling, packaging, storage, and transport procedures enhance the development of fungi, leading to the increased probability of mycotoxin production *(21–23)*. In addition, high humidity and elevated temperatures enhance the growth of fungi and, subsequently, increase the risk of mycotoxins present *(26)*. To prevent the production of mycotoxins, it is crucial to follow good agricultural and manufacturing practices and to control both temperature and humidity, especially during storage *(47)*.

AFs are known for extreme toxicity and adverse effects. Of all the AFs, AFB1 has the highest toxicity, followed by AFM1, AFG1, AFB2, and AFG2 *(47)*. AFs are

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genotoxic, carcinogenic, teratogenic, mutagenic, hepatotoxic, and immunosuppressive *(44)*. The International Association for Research on Cancer classified AFB1, AFB2, AFG1, and AFG2 as a group 1 carcinogen *(47)*.

Rice is one of the world's most important staple foods. Its consumption comes after wheat *(1, 25)*. In the Middle East and North Africa, the consumption is, on average, 13 million tons (11,793 kg) per year of which about 7 million tons (907 kg) were imported. According to the Food and Agriculture Organization, rice represents 27% of the global energy uptake and 20% of the dietary protein in developing countries *(13)*. There are more than 40,000 varieties of rice cultivated in the world. Rice is widely categorized on the basis of the shape or method of processing *(1)*. According to the Food and Agriculture Organization, during inappropriate storage circumstances, 15% of cultivated rice is thrown away every year because of fungi contamination along with other harmful species *(3)*. Therefore, mycotoxin contamination is an important global economic and food safety concern *(34)*. Several studies revealed the contamination of rice with AFs in Sri Lanka, Bangladesh, Japan, the People's Republic of China, Vietnam, Thailand, India, the Republic of the Philippines, South Korea, the United Arab Emirates, Turkey, Tunisia, Nigeria, Cote d'Ivoire, Uruguay, Brazil, Scotland, the United States, the United Kingdom, Austria, Iran, and Sweden *(5, 17)*. The EU established maximum levels of AFB1 and total AFs (2 and 4 μg/kg, respectively) in rice for human consumption and also implemented maximum levels of AFB1 and total AFs (5 and 10 μg/kg, respectively) in rice before ingestion *(1)*. Regarding the AF analysis in food and feed, high-performance liquid chromatography (HPLC) without or with a fluorescence detection, liquid chromatography coupled to a mass spectrometry detector, thin-layer chromatography, and enzyme-linked immunosorbent assay (ELISA) are the main analytical methods used for the quantification of these mycotoxins *(1, 16)*. HPLC is the "gold standard" for measuring AFB1 in foodstuffs. It is known for its high sensitivity, specificity, accuracy, easy usage, and reproducibility of results, yet it is expensive and requires skilled personnel *(16)*. On the other hand, ELISA is highlighted as one of the most used techniques for AFB1 analysis because of its easy execution, sensitivity, low cost, adaptability, safety, high throughput, and minimal sample extraction and sample volume need *(35)*.

Recently, Lebanon witnessed an unprecedented economic and political crisis, rendering the control over the food supply almost absent. Also, new brands have been flooding the market, putting the health of consumers at risk. In addition, there has been constant increase in the prevalence of cancer in Lebanon *(38, 41, 49)*. Furthermore, the country experienced unprecedented power supply shortages, resulting in poor atmospheric conditions for storage and retail facilities, which might lead to mold growth and subsequent AFB1 production in poorly stored dry food products. Until now, no study was performed in Lebanon to assess the safety of rice for AFB1 and to assess the risk associated with the consumption of this staple product. Therefore, our study aimed to determine AFB1 in packed rice marketed in Lebanon and to evaluate the exposure levels from rice consumption and the associated liver cancer risk from this toxin.

MATERIALS AND METHODS

Rice sample collection. A Lebanese market was screened for white, parboiled, and brown packed rice brands in 2020, and 62 brands were identified. Of 61 brands, 44 were collected twice in February and May 2021, while the remaining 17 brands were found in the market at either the first or second collection but not both. Rice bags (total of 105) were stored at −18°C until analysis.

AFB1 determination. Determination of AFB1 in rice was done with the ELISA technique. For this, the RIDASCREEN Aflatoxin B1 30/15 test kit (product R1211; R-Biopharm, Darmstadt, Germany) was used. The test kit was sufficient for 96 determinations (including the calibration curve).

Per the kit manual, a rice sample was ground and thoroughly mixed. Then, 5 g of the ground sample was weighed and transferred to a centrifuge tube with 25 mL of 70% methanol. Each tube was shaken vigorously with a vortex for 3 min and centrifuged (3,500 × *g* for 10 min at room temperature). Afterward, 1 mL of the supernatant liquid was diluted with 1 mL of distilled water. Wells were added to the microwell holder for all standards and samples to be used. The standard and sample places were recorded. Then, 50 μL of the standard or the prepared sample was pipetted into separate wells. Afterward, 50 μL of enzyme conjugate and 50 μL of antibody solution were added to each well. The plate was manually shaken and incubated for 30 min at room temperature. The liquid was poured out of the wells, and the microwell holder was tapped upside down three consecutive times on a clean paper towel to remove any existing liquid from the wells. The wells were loaded with 250 μL of washing buffer and poured out. The washing procedure was performed two more times. Moreover, 100 μL of substrate or chromogen was added to each well, and the plate was manually shaken and incubated for 15 min at room temperature in the dark. Finally, 100 μL of stop solution was added to each well, and the absorbance was measured at 450 nm. Reading and quantification were done within 15 min of adding a stop solution by using a microtiter plate spectrophotometer. Analysis was performed in two replicates. The estimation of the AFB1 concentration relied on plotting the standard curve that was illustrated on the basis of the absorbance of the known concentration of AFB1 standards (0, 1, 5, 10, 20, and 50 μg/kg). The AFB1 concentration in micrograms per kilogram corresponding to the absorbance of each sample was read from the calibration curve by using the cubic spline function of the RIDASOFT Win software (R-Biopharm). The limit of quantitation (LQ) was determined by calibration curve method by using the following equation: $LQ = 10\,\sigma/s$, where σ is the standard deviation of blank response and *s* the slope of calibration *(7)*. The LQ calculated was 0.04 μg/kg.

Moisture determination. Two grams of the ground rice was weighed and added to the crucible. Crucibles were placed in an air oven at 130 ± 3°C for 1 h. The crucibles were taken out of the oven and cooled in a desiccator prior to weighing, as soon as they reached room temperature. The weight of the crucible with the dried sample was recorded. Moisture was calculated from the weight difference of rice *(4)*.

Exposure to AFB1 assessment. The average consumption of rice in Lebanon (grams per kilogram of body weight per day) was determined by using a food frequency questionnaire that included

all rice, along with the frequency and number of consumed portions per day, week, and month, for each dish. The questionnaire was translated into Arabic by a sworn translator and back translated to English to validate the translation. Both versions were piloted to assess clarity and the average time needed for its completion. In compliance with social distancing measures, after obtaining consent from the university's institutional review board, and using a cross-sectional observational design, data were collected via a short 15-min, phone-based questionnaire. The completion of the questionnaire was voluntary and anonymous. The food frequency questionnaire was completed by 500 participants (53% females and 47% males). Different governorates were proportionally represented according to the number of households in each of them.

Exposure level to AFB1 from rice consumption in Lebanon can be then calculated by multiplying the average AFB1 concentration detected in the collected samples by the average rice consumption determined from the food frequency questionnaire *(18, 28),* as follows:

$$\text{Exposure (ng/kg of body weight per day)} = \frac{\text{contamination level (ng/g)} \times \text{amount consumed (g/day)}}{\text{body weight (kg)}}$$

Statistical analysis. The AFB1 concentration was determined as a mean of two replicate measures. Data were coded and entered into Excel (Microsoft Corporation, Redmond, WA) and extracted to SPSS version 27 (IBM Corporation, Armonk, NY) for further analysis. Testing for normal distribution of the AF concentration showed a strong positive skew in the data caused by three large values deemed to be outliers that were removed for analysis (1, 1.20, and 2.08 μg/kg). After removal of the outliers, AFB1 concentration was shown to have a normal distribution and hence was analyzed by using parametric techniques. Mean and standard deviations were used to assess central tendency and measure of spread. The difference in means between groups was tested by using the independent *t* test for two groups and analysis of variance (ANOVA) *F* test for more than two groups. When the ANOVA *F* test showed statistical significance, post hoc analysis was carried out by using the Bonferroni correction for pairwise comparisons, correcting for the familywise type I error. All analyses were carried out at the 0.05 significance level. Independent variables were packing season, country of packing, country of origin, presence of a food safety management system (FSMS), grain size, and time between packing and purchasing.

RESULTS AND DISCUSSION

To our knowledge, this is the first study to assess the safety of packed rice marketed in Lebanon for AFB1 content and to determine the exposure levels to AFB1 from rice consumption and the associated liver cancer risk from this mycotoxin. AFB1 was detected in 105 (100%) of 105 rice samples tested. The overall average (±standard deviation) of AFB1 in the 105 rice samples was 0.5 ± 0.3 μg/kg. The level of contamination ranged between 0.06 and 2.08 μg/kg. The range of AFB1 in rice samples collected from Lebanon (0.06 to 2.08 μg/kg) was higher than those reported in other countries. For example, in Turkey, the AFB1 concentration had a range between "not detected" to 1.86 μg/kg in rice samples obtained from five provinces in the eastern side of the country *(6)*. Sun et al. *(42)* found that AFB1 was detected in all rice samples collected from China and ranged from 0.1 to 1.4 μg/kg. Al-Zoreky and Saleh *(3)* measured AFB1 in packed basmati, white, parboiled, and brown rice sold in Saudi Arabia and found that AFB1 contamination ranged from 0.014 to 0.123 μg/kg, which was within the EU limits. On the other hand, our findings were lower compared with two neighboring countries, the United Arab Emirates and Egypt. As a matter of fact, in the United Arab Emirates, the level of AFB1 contamination ranged between 1.2 and 16.5 μg/kg in short- and long-grain rice *(27)*. In Egypt, the level of AFB1 contamination ranged between not detected and 19.8 μg/kg in rice grains collected from three different districts *(20)*.

TABLE 1. *Effect of different parameters on AFB1 in rice*

Variable	*n*	Mean (μg/kg)	SD (μg/kg)	*P* value
Packing season (Lebanon as country of packing)				
Fall and winter	45	0.46	0.21	
Spring and summer	12	0.37	0.21	0.187
Country of packing				
Lebanon	63	0.44	0.21	
Other countries	39	0.52	0.22	0.093
Country of origin				
Developing (India, Pakistan, Thailand, China)	70	0.45	0.19	
Developed (United States, Italy)	24	0.49	0.26	
Not available	8	0.59	0.23	0.202
FSMS				
Present	33	0.47	0.21	
Absent or not known	69	0.47	0.22	0.967
Grain size				
Long	66	0.48	0.19	
Short and medium	36	0.45	0.25	0.586
Time between packing and purchasing				
1–9 wk	22	0.48	0.21	
10–19 wk	16	0.43	0.21	
20–29 wk	16	0.41	0.21	
30 wk and above	28	0.47	0.2	0.684

Only 1 (1%) of 105 brands had an average level above the EU limit (2 μg/kg). All rice samples from collection 1 and 2 had a moisture content <14% (recommended limit by the Lebanese Standards Institution) *(19)*.

A significant difference was found between white, parboiled, and brown rice ($P = 0.02$). Brown rice had a significantly higher level of AFB1 (0.64 ± 0.23 μg/kg) compared with white (0.45 ± 0.23 μg/kg; $P = 0.032$) and parboiled (0.45 ± 0.18 μg/kg; $P = 0.020$) rice, while no significant difference was found between white and parboiled rice ($P = 0.999$; Table 1).

As presented in Table 1, no significant difference was found between rice brands packed in fall and winter compared with those packed in spring and summer in Lebanon ($P = 0.187$). In addition, no significant difference was found between rice brands packed in Lebanon compared with those packed in other countries ($P = 0.093$) and between rice from developing countries (India,

Pakistan, Thailand, China), developed countries (United States, Italy), and rice with no country of origin information ($P = 0.202$).

No significant difference was found between rice brands with an FSMS compared with those without an FSMS or without any related information ($P = 0.967$) and between long rice grains compared with short to medium rice grains ($P = 0.586$). On the other hand, no significant difference was found for the time between packing and purchasing of rice bags ($P = 0.684$); however, the brands from collection 1 had a significantly higher level of AFB1 (0.52 ± 0.18 μg/kg) than the same brands from collection 2 (0.40 ± 0.23 μg/kg; $P = 0.016$; Table 1).

A previous study conducted *(30)* in Lebanon, measured the dietary exposure to AFB1 from a total diet study in an adult urban population and estimated the mean concentration of AFB1 in rice and rice-based products by using liquid chromatography. The estimated mean concentration of AFB1 in rice and rice-based products ranged between not detected to 0.010 μg/kg, with this being the lowest among the assessed food groups. The mean concentration of AFB1 in our study was higher compared with the previous study *(30)*. One possible explanation is that Raad et al. *(30)* performed an analysis on cooked rice and rice-based products that included other added ingredients and might have undergone processing. In fact, Park et al. *(29)* showed that the percentage of AFB1 in contaminated rice decreased by 34% upon ordinary cooking and more than 70% by pressure cooking.

The significantly higher level of AFB1 in brown rice as compared with white and parboiled rice ($P = 0.02$) was consistent with the literature findings *(2, 11, 37)*. For instance, Sales and Yoshizawa *(37)* demonstrated that AFB1 levels ranged between 0.03 to 8.33 μg/kg in brown rice and not detected, –1.97 μg/kg, in polished rice in the Republic of the Philippines. In addition, when assessing the effect of milling on AF levels, a 78% decrease in mean AF levels was shown from the brown rice to the regular milled rice ($P \leq 0.05$). Another study performed in Brazil showed that among the analyzed rice and its subproduct samples, the average AFB1 levels were 9.09, 6.09, 38.65, and 5.6 μg/kg in rice, rice husk, rice bran, and broken rice, respectively *(2)*.

Our study explored the seasonal effect of rice packing in Lebanon on the AFB1 level in rice. In general, the spring and summer seasons in Lebanon are recognized by having high temperature and humidity levels, which increase mold growth and, therefore, the contamination level of AFB1 in food. In our study, no significant difference was found between rice brands packed in fall and winter compared with those packed in spring and summer. However, the results were in line with the percentages of moisture content of all rice grains in our samples that were below the maximum level of 14% of the weight, which could be attributed to proper humidity and temperature control in the packing facilities. Our results are in line with Elaridi et al. *(9)* in which no significant difference was found between fall and winter and spring and summer for the mycotoxins found in baby formula marketed in Lebanon.

This study further demonstrated no significant difference between rice packed in Lebanon and rice packed in other countries (Table 1). When assessing the association between the country of origin of rice, whether developed, developing, or not available, and the level of AFB1 in the samples, the results were also not significant. Nonetheless, 8% of our analyzed samples had no information regarding the country of origin of rice, which could also mask the true effect of this independent variable.

In the present study, there was no statistically significant difference between the presence or absence of an FSMS or no information about an FSMS system and the level of AFB1 in rice. It is possible that the significance could not be detected because around 68% of the brands had no information regarding the FSMS. Therefore, to not make assumptions, we combined them into an "absent or not known" category. However, the lack of information regarding FSMS does not erase the probability toward the presence of an unillustrated FSMS on the package. On the other hand, it is also highly possible to have industries with FSMS that do not abide by the food safety guidelines or present fake certificates. It is also important to acknowledge the difficulty of developing countries and emerging economies in complying with food safety standards *(45)*. Nonetheless, AFB1 contamination can occur in rice during the cultivation process before being exported to other countries, which adds higher requirements on FSMS. Thus, it is crucial to establish an integrated system on the basis of the hazard analysis and critical control point approach from field to consumer to control AFB1, so it does not exceed the limits set by the legislation. Following good agricultural, storage, manufacturing, and distribution practices are important to decrease, as much as possible, the level of AFB1 before packing rice by reputable industries *(10)*.

In our samples, long-grain rice had a higher concentration of AFB1 than short-grain rice. Although our result did not reach significance, it was in line with other studies *(27, 33)*. When performing the survey of the occurrence of AFB1 in rice consumed in the United Arab Emirates, Osman et al. *(27)* found that the mean concentration of AFB1 in sound (1.3 ± 1.2 μg/kg), moldy (15.7 ± 0.9 μg/kg), and insect-damaged (17.4 ± 2.1 μg/kg) long-grain rice was higher than sound (1.3 ± 0.6 μg/kg), moldy (10.4 ± 1.3 μg/kg), and insect-damaged (13.8 ± 0.3 μg/kg) short-grain rice. Moreover, Reiter et al. *(33)* found that of 71 analyzed long-grain rice samples, 24 were AFB1 positive, with a concentration ranging from 0.45 to 9.40 μg/kg, while of the five analyzed short-grain rice samples, none was found to be AFB1 positive. According to the Lebanese Standards Institution, long-grain rice is characterized by having a length >6 mm, while short-grain rice is characterized by having a length ≤ 5.2 mm *(19)*. Therefore, this higher level of AFB1 in long-grain rice could be due to the higher surface area of this type of rice that might attract more molds and thus AFB1.

When assessing the time between packing and purchasing of rice brands and the level of AFB1 in rice, no significant association was found. Therefore, we speculate that packaging and good storage of rice may decrease environmental influence on the quality of rice. In

addition, we purchased the rice bags from reputable supermarkets that tend to have good storage practices.

Our results showed a significant difference ($P = 0.016$) between the brands of both collections and the level of AFB1. This difference could be due to the inconsistency of the manufacturing practices at the processing and packing sites that increase the susceptibility of AFB1 contamination in rice. Inadequate storage conditions of temperature and humidity and not discarding rice grains with symptoms of fungal contamination can lead to an increased contamination level *(10)*. In fact, Tang et al. *(43)* demonstrated that the risk of AF accumulation was high in rice samples with high proportions of impurities and chalky grains.

For AFs, the tolerable daily intake is not considered a safety factor because the intake of those toxins must remain as low as possible. Accordingly, the provisional maximum tolerable daily intake of 1 ng/kg of body weight per day of AF might be considered a guiding value when evaluating the risk of AF from food *(48)*. Using the data collected from the food frequency questionnaires, the average body weight of participants was 70 kg, while the average daily rice consumption per capita was found to be 68.7 g. As a general rule, 1 cup (240 mL) of uncooked rice will equal about 3 cups (720 mL) of cooked rice *(46)*; thus, 68.7 g of cooked rice is equivalent to 22.9 g dry rice per capita per day. AFB1 was not found to be affected by cooking *(36, 47)*. On the basis of the range (0.06 and 2.08 μg/kg) and average (0.5 μg/kg) of AFB1 levels in our study, the calculated daily exposure to AFB1 ranged between 0.02 and 0.7 ng/kg of body weight per day, with an average of 0.16 ng/kg of body weight per day, which is below the provisional maximum tolerable daily intake.

To our knowledge, no study has assessed the exposure of the Lebanese population to AFB1 from rice consumption. However, the average dietary exposure to AFB1 of an adult urban population estimated by Raad et al. *(30)* was 0.63 to 0.66 ng/kg of body weight per day. In fact, the exposure level to AFB1 calculated in our study was higher than the dietary exposures to AFB1 from rice and wheat consumption in adults (limit of detection, <0.018 ng/kg of body weight per day) and children (limit of detection, <0.035 ng/kg of body weight per day) from France *(40)*. On the other hand, the exposure level to AFB1 calculated in our study was lower, compared with those reported by other studies. For instance, the exposure level to AFB1 from rice consumption in the Republic of the Philippines was estimated between 0.1 and 7.5 ng/kg of body weight per day *(37)*. In Sweden, the exposure level for high rice consumers was 2 to 3 ng/kg of body weight per day *(14)*. In Iran, it ranged between 1.4 and 5.8 ng/kg of body weight per day *(31)*. In Pakistan, the mean level of exposure to AFB1 from rice and rice products ranged between 22.2 and 22.3 ng/kg of body weight per day *(17)*. Therefore, even though the results from different studies are useful references, the comparisons should be delicately assessed because the studies may be different in terms of methodology, model used to assess the dietary exposure, analytical method, types of rice and rice products included in the studies, and consumption patterns that might change between different locations and over time. Therefore, if rice presents a high source of AFB1 in a specific country, it might not be the case for other countries. For Lebanon, Nasreddine et al. *(24)* proved that the consumption of cereals, including refined grains, such as white rice, has increased from 1997 to 2008 and 2009. Thus, even though the calculated average daily exposure to AFB1 in our study is not very high, it is very important to reduce the levels as much as possible to prevent the AFB1 toxic effects with higher consumption of rice.

The strengths of our study include that it was the first of its kind in Lebanon to assess the safety of packed rice marketed in the country, in terms of AFB1 content, and to determine the exposure levels to AFB1 from the rice consumption and the associated liver cancer risk from AFB1. Previous studies on mycotoxins in Lebanon tackled breast milk, infant formulas, and dairy products *(8, 9, 15),* but not on cereals, in particular, rice. In addition, analysis was done on packed rice, as the majority of the Lebanese population purchase packed rice. Most of our samples were Lebanese brands due to the current Lebanese pound exchange rate crisis. Imported food products have become no longer affordable to the majority of Lebanese citizens; thus, there is a shift toward purchasing local and more affordable brands. As for the limitations of our study, there were some outliers in the results. This might be due to the high chance of false-positive or false-negative results caused by insufficient blocking of the surface of the microtiter plate immobilized with an antigen. To address this in future studies, analysis should be done in triplicate for more accuracy. Moreover, around 50% of the samples had no information regarding the FSMS. We could not contact all food companies and gather straight answers, as most of them were not completely cooperative, which explains why we combined them into the absent or not known category. Also, around 20% of our samples did not have production date information. Thus, this might have masked the real association because we could not assess the packing season effect of those brands on the level of AFB1. Nonetheless, unpacked rice samples were not included because of mobility restrictions due to the coronavirus disease 2019 pandemic lockdown and road closures due to security problems in the country.

In conclusion, rice is one of the world's main staple foods. AFB1 contamination in rice is highly present around the world. Our study showed that 99% of the tested rice samples were in compliance with EU and Lebanese Standards Institution limits in terms of AFB1 contamination. Brown rice had higher AFB1 levels than white and parboiled rice, and a significant difference was found between both collections for the same brands. Our study suggests that AFB1 contamination of rice marketed in Lebanon is currently not a major public health concern. However, surveillance strategies and monitoring programs must be routinely performed to ensure minimal AFB1 contamination of rice. Nonetheless, it is advised to purchase packed rice brands, with FSMS certification, and from reputable food markets, in addition to properly store the rice within households, to decrease the risk of AFB1 contamination. Future studies should assess the level of AFB1 in unpacked rice sold in different areas and food markets

across Lebanon for a general insight into the quality of rice purchased and consumed in Lebanon. Furthermore, because rice as a crop is not consumed raw, additional studies should consider a pragmatic approach in which samples are produced in a manner similar to how they are consumed. In addition, routine monitoring must be conducted for smuggled and emerging brands in the Lebanese market.

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