

A Brief Review: Occurrence of Aflatoxins in raw and parboiled rice in Sri Lankan market

ABSTRACT

Contamination of both raw and parboiled rice in Sri Lankan market with Aflatoxins is a crucial health hazard as Aflatoxins are carcinogenic and immune suppressive. Parboiled rice is found to be more vulnerable for the occurrence of Aflatoxins due to the quality changes happens within the kernel during the process of parboiling. Starch inside the parboiled rice kernel appears to be a better substrate for mould growth and high moisture levels are often available within parboiled rice kernels due to improper drying. Out of the two types of parboiling practiced within Sri Lanka cottage parboiling remains safer with compared to commercial level parboiling. However, Sri Lankans has a potential risk of being exposed to Aflatoxins as a result of consuming both raw and parboiled rice contaminated with Aflatoxins.

Key words: Aflatoxins; Rice; Parboiling; Sri Lanka.

1. INTRODUCTION

Aflatoxins are basically identified as the secondary metabolites of fungi in genus *Aspergillus* such as *A. flavus*, *A. parasiticus*, *A. nomius* and *A. stellatus*. Aflatoxin B1, Aflatoxin B2, Aflatoxin G1, Aflatoxin G2, Aflatoxin M1 and Aflatoxin M2 are the types of Aflatoxins produced by these filamentous fungi while aflatoxin B1 appears as the most hazardous and classified under group 1 carcinogens by the International Agency for Research on Cancer (IARC). Aflatoxins are widely available in a variety of food commodities including cereals such as rice, corn, wheat and barley [1, 2, 3, 4, 5]. Further, tropical and sub-tropical climatic conditions like high temperatures, precipitation and humidity exacerbates the mould infestations subsequently leading to the Aflatoxin occurrence. Thus, researchers have reported that Aflatoxins are frequently detected from foods in tropical countries as a result of hot humid climate, poor irrigation practices, poor pest management and inappropriate storage facilities [6, 7, 8, 9].

25% of agricultural food commodities in the world are contaminated with mycotoxins including Aflatoxins. These foods are subjected to contamination at different stages from “farm to fork” [10, 4, 11, 12, 13, 14]. Presence of Aflatoxins in foods is identified as a critical health issue due to the associated carcinogenicity of Aflatoxins. Moreover, Aflatoxins cause immune dysfunctions, mutagenicity and genotoxicity. Due to the possible health risks many countries have imposed strict legislations to control the level of Aflatoxins in food commodities [9, 15]. Inadequacy of quality control standards in Sri Lanka is a major reason for human exposure to Aflatoxins and it is essential to impose proper standards to ensure food safety. However, Sri Lanka generally adheres to the quality standards imposed by the European Union based on its import and export markets. Hence a maximum permissible level (MPL) of 2 µg/kg and 4 µg/kg are often maintained respectively for Aflatoxin B1 (AFB1) and total Aflatoxins [16, 17, 18, 19].

Rice, *Oryzae sativa* L. is the staple food in Sri Lanka which is widely produced and consumed throughout the country. Sri Lanka is nearly self-sufficient with rice, approximately fulfilling 95% of domestic rice requirements with its national production. In the year 2019 annual production of paddy was 4,592,000 metric tons as per the records of the Central Bank of Sri Lanka [20, 21, 22, 23]. Tropical climate in Sri Lanka facilitates the optimum conditions for paddy growth as well for fungal colonization. Furthermore, storage of paddy for months in poor storage conditions aggravates the mould growth. **Temperature and relative humidity of storages are quite high and estimated as 27°C and 78% respectively.** As a result Aflatoxin contaminated rice has been reported from Sri Lanka in several instances and few other South-East Asian countries also have records of aflatoxin in rice. This causes human exposure to Aflatoxins through consumption of rice [6, 7, 8, 24]. As a person consumes a substantial amount of rice per day in Sri Lanka, even a small dose of Aflatoxin available in rice can cause a huge harm on the health of Sri Lankans [21, 25, 26]. Although this is a crucial health hazard as a developing country Sri Lanka has very scarce data sources on this regard. **Being the staple rice and its associated processing techniques like parboiling needs more attention and close monitoring.** Insufficiency of data is also responsible for the inadequacy of proper regulatory measures. Therefore this brief review aims to present the gravity of this

issue and to bring out the timely need of more research works by employing the limited data available in a comprehensive manner. Only three such studies were available within Sri Lanka and all those studies were taken into account.

2. PARBOILING

Rice is milled either without parboiling as raw rice or after parboiling as parboiled rice. Parboiling is a process where rice is soaked in water overnight followed by pre-cooking rice within the husk itself. Subsequently, the precooked rice is sun dried and then passed through a rubber roll sheller and a polisher in order to remove the husk and outer bran layer respectively. Parboiled rice is very popular within Asian continent and almost 20% of global rice production is turned into parboiled rice before consumption [20, 27, 28]. Parboiling of rice causes numerous changes in the color, texture, nutritional composition and shelf life of rice. Parboiled rice is preferred by some consumers due to these changes; particularly due to the changes of nutritional aspects. Parboiling causes the gelatinization of starch forming amylose-lipid complexes and inducing disulfide bonds between the protein molecules [28, 29]. Basically two types of parboiling practices are available in Sri Lanka,

2.1 COMMERCIAL PARBOILING

Commercial parboiling involves large scale production of parboiled rice in large concrete tanks. In this commercial scale parboiling water is often reused due to the associated practical issues and this causes high contamination [27].

2.2 COTTAGE PARBOILING

Household level process where rice is washed and precooked in clay or copper pots of 15L capacity up to the point of grain split. This step is followed by sun drying in open areas while frequent turning [27].

3. EFFECTS OF PARBOILING ON MOULD GROWTH

Soaking rough rice in water causes to reduce the cooking time to save the amount of fuel required for pre-cooking step. As well this step provides the moisture requirement of endosperm starch for gelatinization. The gelatinization of rice starch facilitates nutrition retention within the kernel; specially, vitamins like vitamin B and minerals. Gelatinized starch within the parboiled rice kernel is more susceptible to fungal growth than the endosperm starch in raw rice kernels. Hence this parboiled rice kernel is an ideal substrate for fungal growth and Aflatoxin production. Improper sun drying of precooked rice may result in high moisture contents favorable for mould growth [27, 29, 30].

During the storage, rice packed in jute or polythene bags are stacked in warehouses with poor ventilation for a prolonged time duration which results in the mouldiness of rice. Hence parboiled rice is highly prone to Aflatoxins in comparison to raw rice [21, 27].

A study conducted by Breckenridge et al. in 1986 reported Aflatoxins in both raw and parboiled rice samples of locally available varieties collected from more than 90% of market places collected from wet, intermediate and dry zones of the country. The minimum detectable level of Aflatoxin in the study was 12

$\mu\text{g}/\text{kg}$ and the level of Aflatoxin in different rice samples was compared with UNICEF/WHO/FAO maximum permissible level of $30 \mu\text{g}/\text{kg}$.

Table 1. Aflatoxin B1 contents in raw and parboiled rice samples collected from the three different climatic zones (wet, Intermediate and Dry Zones) in Sri Lanka

Year	Number of Samples tested		Aflatoxin B1 not detected	< $30\mu\text{g}/\text{kg}^*$	$30\mu\text{g}/\text{kg}$
1986	Raw rice	35	32	3	0
	Parboiled Rice	562	493	57	12

[21] * As the minimum detectable level of Aflatoxins is $12 \mu\text{g}/\text{kg}$. The value $<30\mu\text{g}/\text{kg}$ falls within the range of $12-30\mu\text{g}/\text{kg}$

Out of the total Aflatoxin positive 72 rice samples 69 samples were parboiled rice and 12 parboiled samples were containing Aflatoxin B1 levels of $30 \mu\text{g}/\text{kg}$. With these results it was showed that parboiled rice is more susceptible to Aflatoxins than raw rice. Nevertheless, number of raw rice samples employed was not sufficient to conclude it.

In a later study conducted by Bandara et al., in 1991 concluded that parboiled rice is highly preferred by fungi of genus *Aspergillus* over raw rice and incidence of Aflatoxin presence is higher in parboiled rice than raw rice. During the study AFB1 and AFG1 was tested while both AFB1 and AFG1 levels in parboiled rice remained higher than that of raw rice. The highest AFB1 level was $185 \mu\text{g}/\text{kg}$ and AFG1 content $963 \mu\text{g}/\text{kg}$, was detected from parboiled rice samples [20].

In 1991, commercial parboiling and cottage parboiling was compared with respect to susceptibility to Aflatoxins. Aflatoxin contents in rice produced by commercial parboiling (AFB1 $60-92 \mu\text{g}/\text{kg}$) were significantly higher than that in rice produced by cottage level parboiling (AFB1 $12-29 \mu\text{g}/\text{kg}$). Further this study presented that longer soaking duration causes to enhance the susceptibility of grains to *A. flavus* resulting in Aflatoxins and this could be reduced by adding a bleaching agent to the soaking water. Furthermore, reusing of soaking water, steeping for long durations, improper sun drying are possible reasons for commercial level parboiling to be more prone for Aflatoxins [27].

4. CONCLUSION

The major focus of this short review was to highlight the risk associated with occurrence of Aflatoxins in rice; inadequacy of data and regulatory standards; effects of parboiling on contamination of rice with Aflatoxins. As per the data found Aflatoxins were detected from raw and parboiled rice within Sri Lanka. Parboiling of rice promotes growth of fungi on rice ultimately causing Aflatoxin occurrence. Moreover, commercial parboiling was concluded as harmful in comparison to cottage parboiling as the chance of being contaminated is high. There are potentials of using novel technologies like chromatographic, electrochemical based sensing etc. in future investigations. Moreover Aflatoxin decontamination techniques should be incorporated into the rice production process.

References

1. Abuagela MO, Iqdiam BM, Baker GL, MacIntosh AJ. Temperature-controlled pulsed light treatment: impact on aflatoxin level and quality parameters of peanut oil. *Food and bioprocess technology*. 2018; 11(7): 1350-1358. <https://doi.org/10.1007/s11947-018-2105-6>.
2. Bordin K, Sawada MM, da Costa Rodrigues CE, da Fonseca CR, Oliveira CAF. Incidence of aflatoxins in oil seeds and possible transfer to oil: a review. *Food Engineering Reviews*. 2014; 6(1-2): 20-28. <https://doi.org/10.1007/s12393-014-9076-9>.
3. Chen L, Molla AE, Getu KM, Ma A, Wan C. Determination of Aflatoxins in Edible Oils from China and Ethiopia Using Immunoaffinity Column and HPLC-MS/MS. *Journal of Aoac International*. 2019; 102(1): 149-155. <https://doi.org/10.5740/jaoacint.18-0106>.
4. Eom T, Cho HD, Kim J, Park M, An J, Kim M et al. Multiclass mycotoxin analysis in edible oils using a simple solvent extraction method and liquid chromatography with tandem mass spectrometry. *Food Additives & Contaminants: Part A*. 2017; 34(11): 2011-2022. <https://doi.org/10.1080/19440049.2017.1363416>.
5. World Health Organization (WHO)-IARC Working Group on the Evaluation of Carcinogenic Risks to Humans and International Agency for Research on Cancer. Some traditional herbal medicines, some mycotoxins, naphthalene and styrene. 2002; 82. Accessed 18 August 2021. Available: <https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono82.pdf>.
6. Al-Zoreky NS, Saleh FA. Limited survey on aflatoxin contamination in rice. *Saudi journal of biological sciences*. 2019; 26(2): 225-231. <https://doi.org/10.1016/j.sjbs.2017.05.010>.
7. Elzupir AO, Alamer AS, Dutton MF. The occurrence of aflatoxin in rice worldwide: a review. *Toxin Reviews*. 2015; 34(1): 37-42. <https://doi.org/10.3109/15569543.2014.984229>.
8. Mahato DK, Lee KE, Kamle M, Devi S, Dewangan KN, Kumar P et al. Aflatoxins in food and feed: an overview on prevalence, detection and control strategies. *Frontiers in microbiology*. 2019; 10: 2266. <https://doi.org/10.3389/fmicb.2019.02266>.
9. Schwartzbord JR, Brown DL. Aflatoxin contamination in Haitian peanut products and maize and the safety of oil processed from contaminated peanuts. *Food control*. 2015; 56: 114-118. <https://doi.org/10.1016/j.foodcont.2015.03.014>.
10. Dutta TK, Das P. Isolation of aflatoxigenic strains of *Aspergillus* and detection of aflatoxin B 1 from feeds in India. *Mycopathologia*. 2001; 151(1): 29-33. <https://doi.org/10.1023/A:1010960402254>.
11. Food and Agriculture Organization (FAO). Worldwide regulations for mycotoxins in food and feed in 2003. *Food and Nutrition paper 81*. 2004. Accessed 06 August 2021. Available: <http://www.fao.org/3/y5499e/y5499e00.htm>.
12. He T, Zhou T, Wan H, Han Q, Ma Y, Tan T et al. One-step deep eutectic solvent strategy for efficient analysis of aflatoxins in edible oils. *Journal of the Science of Food and Agriculture*. 2020; 100(13): 4840-4848. <https://doi.org/10.1002/jsfa.10544>.

13. Li R, Wang XU, Zhou T, Yang D, Wang QI, Zhou YU. Occurrence of four mycotoxins in cereal and oil products in Yangtze Delta region of China and their food safety risks. *Food Control*. 2014; 35(1): 117-122. <https://doi.org/10.1016/j.foodcont.2013.06.042>.
14. Van Egmond HP, Schothorst RC, Jonker MA. Regulations relating to mycotoxins in food. *Analytical and bioanalytical chemistry*. 2007; 389(1): 147-157. <https://doi.org/10.1007/s00216-007-1317-9>.
15. Pankaj SK, Shi H, Keener KM. A review of novel physical and chemical decontamination technologies for aflatoxin in food. *Trends in Food Science & Technology*. 2018; 71: 73-83. <https://doi.org/10.1016/j.tifs.2017.11.007>.
16. Anukul N, Vangnai K, Mahakarnchanakul W. Significance of regulation limits in mycotoxin contamination in Asia and risk management programs at the national level. *Journal of Food and Drug Analysis*. 2013; 21(3): 227-241. <https://doi.org/10.1016/j.jfda.2013.07.009>.
17. European Union (EU). COMMISSION REGULATION (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. 2006. Accessed 08 August 2021. Available: <http://extwprlegs1.fao.org/docs/pdf/eur68134.pdf>.
18. European Union (EU). Commission Regulation (EC) No 165/2010 of 26 February 2010 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards aflatoxins. 2010. Accessed 08 August 2021. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32010R0165&qid=1626496960549>.
19. The Sri Lankan scientist. Aflatoxin another serious health hazard to humans. 2016. Accessed 30 July 2021. Available: <http://scientist.lk/2016/11/22/aflatoxin-another-serious-health-hazard-to-humans/>.
20. Bandara JMR., Vithanage AK, Bean GA. Effect of parboiling and bran removal on aflatoxin levels in Sri Lankan rice. *Mycopathologia*. 1991; 115(1): 31-35. <https://doi.org/10.1007/BF00436418>.
21. Becker-Algeri TA, Castagnaro D, de Bortoli K, de Souza C, Drunkler DA, Badiale-Furlong E. Mycotoxins in bovine milk and dairy products: A review. *Journal of food science*. 1986; 81(3): R544-R552. <https://doi.org/10.1111/1750-3841.13204>.
22. Central Bank of Sri Lanka (CBSL). Economic and Social Statistics of Sri Lanka. 2020. Accessed: 27 May 2021. Available: https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/statistics/otherpub/ess_2020_e1.pdf.
23. Rice Research and Development Institute (RRDI)- Department of Agriculture. Rice Cultivation. 2021. Accessed 19 July 2021. Available: https://doa.gov.lk/rrdi/index.php?option=com_sppagebuilder&view=page&id=42&lang=en.

24. Prietto L, Moraes PS, Kraus RB, Meneghetti V, Fagundes CAA, Furlong EB. Post-harvest operations and aflatoxin levels in rice (*Oryza sativa*). *Crop Protection*. 2015; 78:172-177. <https://doi.org/10.1016/j.cropro.2015.09.011>
25. Nisa A, Zahra N, Hina S. Detection of aflatoxins in rice samples. *Bangladesh Journal of Scientific and Industrial Research*. 2014; 49(3): 189-194. <https://doi.org/10.3329/bjsir.v49i3.22134>
26. Munasinghe J, De Silva A, Weerasinghe G, Gunaratne A, Corke H. Food safety in Sri Lanka: problems and solutions. *Quality Assurance and Safety of Crops & Foods*. 2015; 7: 37-44. <https://doi.org/10.3920/QAS2014.x007>.
27. Bandara JMRS, Vithanage AK, Bean GA. Occurrence of aflatoxins in parboiled rice in Sri Lanka. *Mycopathologia*. 1991; 116(2): 65-70. <https://doi.org/10.1007/BF00436366>.
28. Sittipod S, Shi YC. Changes of starch during parboiling of rice kernels. *Journal of Cereal Science*. 2016; 69: 238-244. <https://doi.org/10.1016/j.jcs.2016.03.015>
29. Balbinoti TCV, de Matos Jorge LM, Jorge RMM. Modeling the hydration step of the rice (*Oryza sativa*) parboiling process. *Journal of Food Engineering*. 2018; 216: 81-89. <https://doi.org/10.1016/j.jfoodeng.2017.07.020>
30. Toteja GS, Mukherjee A, Diwakar S, Singh P, Saxena BN, Sinha KK et al. Aflatoxin B1 contamination of parboiled rice samples collected from different states of India: A multi-centre study. *Food additives and contaminants*. 2018; 23(4): 411-414. <https://doi.org/10.1080/02652030500442490>.