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Occurrence of Aflatoxins in Rice and Rice Products and By-products of Rice: A Review

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요 약

아플라톡신(aflatoxin)은 곰팡이의 2차 대사산물이며 인간발암원으로 보건상 위해를 준다. 쌀은 아플라톡신을 생성하는 곰팡이인 *Aspergillus flavus*와 *A. parasiticus*에 좋은 기질이다. 이 연구에서는,쌀과 쌀제품 및 쌀부산물에서 전세계적으로 나타나고 있는 아플라톡신 오염 정도와 오염 수준에 대하여 고찰하였다. 아플라톡신 오염 정도와 오염 수준은 시료의 유형과 시료채취 지역에 따라 다르게 나타나는 것으로 보인다. 쌀과 쌀제품 2,511 시료 중 36.6%에서, 그리고 쌀부산물 374 시료 중 57.8%에서 아플라톡신이 검출되었다. 이들 시료에서 aflatoxin B_1 및 total aflatoxin 오염도는 0-185 μg/kg였다. 일부 백미 시료에서는 20 μg/kg을 초과하는 시료가 있었다. 쌀의 아플라톡신 관련 위생관리지표를 고안할 수 있는 기초자료를 제공하기 위하여 쌀의 아플라톡신 오염에 대한 모니터링이 필요하다. 또 쌀과 쌀제품 생산의 모든 단계와 저장에서 아플라톡신 관리를 위한 통합적 접근법이 필요하다. 가축을 아플라톡신으로부터 보호하는 전략은 인간집단을 보호할 수 있는 효과적인 접근법이 될 수 있다.

Keywords: aflatoxins, rice and rice products, by-products of rice

I. Introduction

Aflatoxins (AFs) are a group of toxic secondary metabolites produced by *A. flavus* and *A. parasiticus*. Aflatoxins have been considered as probable human carcinogen by the International Agency for Research on Cancer (IARC 2002). Aflatoxin B_1 (AFB_1), the most commonly occurring toxins in this group (Williams *et al.* 2004), has been found to be one of the most potent carcinogens. The frequent contamination with AFs of agricultural products is not only negative economic problems but also harmful both to human and animal health, because of their carcinogenic, mutagenic, and teratogenic nature (Smith and Moss 1985). In order to minimize human exposure to AFs, rigid regulations have been established by government agencies in controlling aflatoxin levels in foods and feeds (Food and Agriculture Organization 2003). Recently, there has been a new interest in the risk of exposure to AFs due to the consumption of staples, following reports of high levels of contamination in maize and rice in Kenya and China (International Society for Infectious Diseases 2001, 2004).

Rice is one of the better substrates for the aflatoxigenic fungi. AFB_1 is the mycotoxin which has been reported most frequently in rice (Mollenhauer 1979). Rice is a staple food for 50% of the world population. Rice ranks second to wheat with the highest per capita consumption among the cereal crops (FAO 2005). Throughout Asia rice is the main source of carbohydrates and the most important agricultural product. In order to get safe rice, rice should be safely planted, harvested, stored, processed, and distributed. One of the major causes of postharvest deterioration is contamination with the aflatoxigenic fungi and insect infestation which occur during threshing, shelling, milling, drying, and storage. By-products of rice plant such as the hulls and bran generated after polishing are often used as feeds or feed ingredients for domestic animals. Actually, about 2% of rice produced is used for animal feeds (FAO 2003). The consumption of animal products such as meat and milk derived from

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animals fed aflatoxin-contaminated by-products of rice also represents another pathway of exposure to aflatoxins. Although several strategies, including chemical or biological control, are being investigated to reduce and eliminate AF contamination of crop, there is no fantastic method to use for foods and feed (Lee and Kim, 2005; Yeo and Kim, 2003; Kim, 1995; Smith and Moss 1985; Phillips *et al.* 1993; Pluyer *et al.* 1987).

Because of the high consumption and daily intake of rice and by-products of rice in Asia, it is very important to monitor AF contamination in these commodities. This review was performed to investigate natural occurrence of aflatoxins in rice, rice products and by-products of rice and to prepare background data for developing a hygienic index of aflatoxin control in rice.

II. Incidence of AF in Rice and Rice Products

A total of 2,511 samples of rice and rice products were surveyed in Asia, Africa, Europe, North America, and South America (Table 1). The cases were reported in the Philippines more times than any other country.

Incidence of AF varied between less than 1% to 100% (average: 36.6%). Yoshizawa (1993) reported <2% incidence in more than 400 samples of rice from Asia and Africa in an earlier review. In this review high incidences of AF contamination in rice and rice products have been reported in the Philippines (85.5-100%), the United Kingdom (100%), Nepal (75-100%), Guatemala (50%), and Thailand (50%). In the Philippines, a study reported by Salamat (1978) showed relatively low incidence (30%) of AF in the rough rice samples. Although 100% incidence in polished rice was observed in India, only one sample was surveyed.

Studies have shown that brown rice or polished rice can accumulate high levels of AF when artificially inoculated with aflatoxigenic fungi of *Aspergillus flavus* or *A. parasiticus* (Carballo and Miguel 1987, Kim 1995, Kim and Lee 1996, Kim 1998, Begum and Samajpati 2000). However, in natural occurrence, AF production in rice was relatively lower.

III. Levels of AF in Rice and Rice Products

In the Philippines, a survey (Salamat 1978) on the AF content of various food items showed relatively low natural levels of AF in the rice samples. It showed that milled rice, rough rice, rice bran and pop rice contained AF in the levels of 12, 15, 16, and 3 μg/kg, respectively. In another earlier survey, moldy unhulled rice from storage had no detectable AF while polished rice stored for 2 years contained 5 μg/kg AF (Santamaria *et al.* 1972). In recent years AF level of rice in the Philippine (Sales and Yoshizawa 2005) showed 0-2.7 μg/kg and 0.03-8.7 μg/kg AF in brown and polished rice, respectively. AF levels appear to have decreased drastically from values reported for Philippine polished rice surveyed from 1967 to 1982 (6% with AF levels >20 μg/kg). This difference could result from an improvement in postharvest systems in the country resulting in higher rice quality. AF levels of rice products in the Philippines have been variable from 1974 to 2005 (0-3 μg/kg).

In Thailand, a survey (Suttajit 1999) reported that 6.3% of uncooked rice grains showed AFB_1 levels higher than the permissible level (20 μg/kg) for human consumption. Another survey showed that one of the two rice samples from Thailand contained 0.01 μg/kg AFB1 (Suprasert and Kamimura, 1999). Another survey (Lipigorngoson *et al.* 2003) reported AF levels of 0.1-0.3 μg/kg in polished rice imported to Japan from Thailand and Pakistan. In rice noodles, the AFB_1 level was 20.2 μg/kg, and decreased to 15.8 μg/kg after cooking (Suttajit *et al.* 1999). In rice samples from the Ratbui district of Thai, only 2 of 364 were contaminated with AF, and maximum AF levels of the rice was 98 μg/kg (Shank *et al.* 1971).

In Malaysia, the levels of rice flour (7 samples), rice and products (30 samples), stored paddy (77 samples), and rice grains (84 samples) were 4 μg/kg AFB_1, 2-7 μg/kg AFB_1, 2-8 μg/kg AFB_1, and 4-96 μg/kg total AF, respectively (Mat and Siong, 1984, Mat 1989, Salleh 1997, Abdullah *et al.* 1998, Ali 2000). The number of contaminated samples represented 7% of the total number of samples analyzed.

Table 1. Occurrence of aflatoxin in rice and rice products from 1970s~2000s

Reporter/Year	Sample type	No. of samples analyzed	Positive samples		Conc. (μg/kg)	Country
			No.	%		
Lucas *et al.* 1971	Preharvest rice	139	43	30.94	>20	Vietnam
Schroeder and Boller 1973	Preharvest rice	425	1	0.24	<2-282	U.S.A.
Stoloff 1976	Preharvest rice	157	2	1.27	5	U.S.A.
Salamat 1978	Rough rice	10	3	30.00	0-18	Philippines
Rivas and Rodricks 1979	Rough rice	-	-	-	>20	Colombia
de Campos and Olszyna-Marzys 1979	Rough rice	6	2	33.33	<8	Guatemala
de Campos and Olszyna-Marzys 1979	Brown rice	18	9	50.00	83 max	Guatemala
Shank *et al.* 1971	Polished rice	364	2	0.55	98 max	Thailand
Santamaria *et al.* 1972	Polished rice	-	-	-	5	Philippines
Van Rensburg *et al.* 1975	Polished rice	-	-	-	3.8 average	Mozambique
Suttajit 1999	Polished rice	20	1	5.00	>20	Thailand
Karki *et al.* 1979	Polished rice	8	6	75.00	<2.5-15 (AFB_1)	Nepal
Sundaram *et al.* 1988	Rough rice	170	-	-	-	India
Muraguri *et al.* 1981	Polished rice	9	1	11.11	Trace	Kenya
Reddy *et al.* 1984	Polished rice	60	12	20.00	23 average	India
Reddy *et al.* 1984	Polished rice	20	6	30.00	43 average	India
Zhen-Zhen 1989	Polished rice	252	33	13.10	5-10	China
Jayaraman and Kalyanasundaram 1990	Polished rice	1	1	100.00	20	India
Almeida *et al.* 1991	Polished rice	90	-	-	-	Brazil
Lee and Kim 1991	Polished rice	88	3	3.41	2.0-6.2 (AFB_1)	Korea
MAFF 1993	Polished rice	14	14	100.00	0.1-17.5	UK
Patel *et al.* 1996	Polished rice	4	-	-	0.1-2.4	UK
Abdullah *et al.* 1998	Polished rice	84	6	7.14	4-96	Malaysia
Pittet 1998	Polished rice	-	-	-	6.8-40	Ecuador
Suprasert and Kamimura 1999	Polished rice	2	1	50.00	0.01	Thailand
Qutet *et al.* 2003	Rough rice	39	3	7.69	285-499 (AFB_1)	Egypt
Sales and Yoshizawa, 2005	Rough rice	4	4	100.00	2.91-3.58	Philippines
Sales and Yoshizawa. 2005	Brown rice	9	9	100.00	0.03-8.66	Philippines
Qutet *et al.* 2003	Polished rice	-	-	-	10	Egypt
Lipigorngoson *et al.* 2003	Polished rice	20	5	25.00	0.1-0.3	Thailand/Pakistan /Bangladesh
Sales and Yoshizawa, 2005	Polished rice	69	59	85.51	<0.025-2.67	Philippines
Mat and Siong 1984, Mat 1989, Salleh 1997, Ali 2000	Rough rice/Polished rice/rice flour	114	8	7.02	2-8	Malaysia
Campbell and Stoloff 1974	Rice products	72	1	1.39	>1	Philippines
Karki *et al.* 1979	Parboiled rice	4	4	100.00	<2.5-12.5	Nepal
Salamat 1978	Pop rice	6	1	16.67	0-3	Philippines
Bulatao-Jayme *et al.* 1982	Rice and rice products	186	71	38.17	30.1 average	Philippines
Bulatao-Jayme *et al.* 1982	Boiled rice	15	3	20.00	0.6 average	Philippines
Bandara *et al.* 1991	Parboiled rice	-	-	-	185 (AFB_1) max.	Sri Lanka
Céspedez and Diaz 1997	Rice meal	22	8	36.36	1.0-52.8 (AFB_1)	Colombia
Suttajit *et al.* 1999	Rice noodle	10	-	-	20 average (AFB_1)	Thailand
Total		2,511	322	36.63		

Samples of polished rice and parboiled rice from Nepal showed AFB_1 levels of <2.5 μg/kg to 15 μg/kg and <2.5 μg/kg to 12.5 μg/kg, respectively (Karki *et al.* 1979). Parboiled rice samples from

Sri Lanka showed maximum AFB_1 level of 185 μg/kg (Bandara *et al.* 1991).

Trace level of AF was detected in 1 polished rice from Kenya (Muraguri *et al.* 1981). In India, AF levels of 20-43 μg/kg in polished rice were reported (Reddy *et al.* 1984, Jayaraman and Kalyanasundaram 1990). Of the 252 samples of polished rice surveyed, 33 (13.1%) were contaminated with AF levels of 5-10 μg/kg (Zhen-Zhen 1989) in China. No detectable AF was found in 90 samples of polished rice from Brazil (Almeida *et al.* 1991).

In Korea, 3 of 88 polished rice samples (3.4%) contained 2.0-6.2 μg/kg AFB_1 (Lee and Kim 1991). For positive samples, the mean concentration of AFB_1 was 4.1 μg/kg.

Polished rice samples from Ecuador and Egypt contained 6.8-40 μg/kg AF (Pittet 1998) and 10 μg/kg AF (Qutet *et al.* 2003), respectively. In Colombia, 8 of 22 rice meal samples intended as feed contained 1.0-52.8 μg/kg AFB_1 (Céspedez and Diaz 1997). Of the 8 samples of rice meal containing AFB_1, 3 showed levels exceeding 20 μg/kg, which is the maximum tolerable level in most countries.

In a limited study on ethnic foods sold in the UK, Indian rice (4 samples) was found to contain 0.1-2.4 μg/kg AF (Patel *et al.* 1996). A surveillance carried out during 1989-1990 (Ministry of Agriculture, Fisheries and Food 1993) showed that all 14 samples of rice examined contained detectable amounts of AFB_1 up to a level of 17.5 μg/kg in one sample. Three (60%) of five samples of rice-based breakfast cereals was positive for AFB_1 (Jarvis 1982). These products or their ingredients originate from tropical countries where climatic conditions increase the potential for AF development compared with conditions in Northern European countries. In light of the stringent regulations set by the EU on AF in foods, importing countries face the challenge of keeping AF levels to a minimum.

Generally, AF contamination is more a problem in the tropics than in the temperate zones, however, considering the transportation of agricultural commodities from one part of the globe to another, AF may be present in rice or rice products sold in any part of the world.

IV. Incidence and Levels of AF in By-products of Rice

A total of 374 samples of by-products of rice were surveyed (Table 2). More cases were reported in the Philippines. Incidence of AF was between 2.7% to 100% (average: 57.8%). High incidences of AF contamination in by-products of rice have been reported in the Philippines (80-100%) and the United Kingdom (72.5-100%). In a survey carried out by Scudamore *et al.* (1997), all of the 40 samples of rice bran contained detectable levels of AF up to a maximum level of 19 μg/kg (13 μg/kg AFB_1 and 6 μg/kg AFB_2). Samples of rice bran and rice

Table 2. Occurrence of aflatoxin in by-products of rice from 1970s-2000s

Reporter/Year	Sample type	No. of samples analyzed	Positive samples		Conc. (μg/kg)	Country
			No.	%		
Salamat 1978	Rice bran	15	12	80.00	0-38	Philippines
Sutikno 1990	Rice bran	136	16	11.76	>20	Indonesia
Balaraman and Gupta 1990, Jayaraman and Kalyanasundaram 1994	Rice bran	44	14	31.82	10-100	India
Scudamore *et al.* 1997	Rice bran	40	40	100.00	19 max	UK
Scudamore *et al.* 1998	Rice bran	40	29	72.50	1-23	UK
Tabata *et al.* 1993	Rice powder/bran	74	2	2.70	0.3-3.6	Japan
Kim and Lee 1996	Brown rice (inoculated)	-	-	-	95.4	Korea
Kim and Lee 1996	Rice bran (inoculated)	-	-	-	18.7	Korea
Thirumala-Devi *et al.* 2002	Rice bran	14	3	21.43	10-100	India
Sales and Yoshizawa, 2005	Rice bran	7	7	100.00	0.27-10.31	Philippines
Sales and Yoshizawa, 2005	Rice hull	4	4	100.00	0.83-10.61	Philippines
Total		374	127	57.80		

hull from the Philippines contained AF at the levels ranging from 0.27 to 10.6 μg/kg (Sales and Yoshizawa 2005). These levels are within maximum permissible levels laid down in the Feeding Stuffs Regulations (Ministry of Agriculture, Fisheries and Food 1995), and are below the maximum level of AFB_1 permitted in straight feeds by the EU (European Commission 2001): 20 μg/kg. However, it may be possible that higher level of AF can be produced in these materials if they are in poor storage conditions. Therefore, monitoring of rice by-products used for feeds and feed ingredients is very important.

V. Summary and Conclusions

This study is a retrospective review on aflatoxin occurrence in rice and rice products and by-products of rice. Incidences and levels of contamination seem to vary depending on the sample type and the location or sampling method. Variability may also be attributed to the storage time and conditions of storage. High AF levels have been found in samples from some countries in Asia and Africa, which can be attributable to inadequate postharvest storage. Incidence of AF in more than 2,500 samples of rice and rice products and more than 370 by-products of rice surveyed all over the world showed 36.6% and 57.8%, respectively. Levels of AFB_1 and total AF in some samples were beyond European Union regulatory limits; some even showed levels above 20 μg/kg, the amount of AF allowed in foods by Codex Alimentarius. Although AF contamination in most of the polished rice and rice products may be considered generally low, frequent consumption of these commodities could result in higher exposure levels and more chronic adverse health effects as compared to other commodities such as peanuts and corn that are known to harbor high levels of AF but consumed less. By-products of rice such as rice hulls and bran are often used as feeds and their ingredients for domestic animals, which in turn are a source of protein for humans. In order to control and reduce AF in these commodities, monitoring is necessary to provide data that can serve as basis for exposure assessment studies. Improved and integrated approaches to control AF and aflatoxigenic fungi at all stages of production, storage, and marketing should be also necessary.

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