AIMS Agriculture and Food, 7(1): 130–148.
DOI: 10.3934/agrfood.2022009
Received: 27 September 2021
Revised: 04 March 2022
Accepted: 14 March 2022
Published: 25 March 2022

http://www.aimspress.com/journal/agriculture

Research article

The prevalence of aflatoxins in different nut samples: A global systematic review and probabilistic risk assessment

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Supplementary Table 1. The aflatoxin concentration in peanut from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Peanut	Egyptian	AFB1	36	6.74	Abdel-Rahman et al, 2019 [1]
		AFT	36	8.17	
Ground nuts	Cameroon	AFB1	35	47	Abia et al, 2013 [2]
Ground nuts	Nigeria	AFT	15	32.26	Adetunji et al, 2018 [3]
Raw Groundnuts	Nigeria	AFB1	26	104.10	Afolabi et al, 2015 [4]
		AFT	26	197.90	
Ground nuts	Ghana	AFT	183	30.34	Agbetiameh et al, 2018 [5]
Peanut	Saudi Arabia	AFB1	1	0.68	AlFaris et al, 2020 [6]
Peanut	Brazil	AFT	104	13.40	Alini Cristini dos Santos et al, 2018 [7]
		AFB1	104	41.70	

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Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Peanut	Malaysia	AFB1	10	1.55	Alsharif et al, 2019 [8]
Peanut	Brazil	AFT	359	14.20	Andrade et al, 2013 [9]
Peanut	Southern Haiti	AFB1	8	58.70	Aristil et al, 2020 [10]
		AFT	8	70.20	
Peanut	Malaysia	AFB1	63	9.00	Arzandeh et al, 2010 [11]
		AFT	63	11.28	
Peanut	Pakistan	AFT	20	2.37	Asif Asghar et al, 2017 [12]
Peanut	Spain	AFB1	4	nd	Blesa et al, 2004 [13]
		AFB1	4	nd	
Peeled	Spain	AFB1	3	2.73	Blesa et al, 2005 [14]
Peanuts		AFT	3	20.73	
Raw peanut	Zambia	AFT	51	0.43	Bumbangi et al, 2016 [15]
		AFB1	41	0.45	
Peanut	Cyprus	AFB1	52	3.00	Christofidou et al, 2015 [16]
Ground nuts	Saudi Arabia	AFT	49	16.50	El tawila et al, 2013 [17]
Peanut	Argentina	AFB1	2	530	FernaÂndez Pinto et al, 2001 [18]
Peanut	Brazil	AFT	35	440	Freitas et al, 1998 [19]
Peanut	Turkey	AFT	7	43	Gürses et al, 2006 [20]
Ground nuts	Turkey	AFB1	151	0.96	Hepsag et al, 2014 [21]
		AFT	151	1.16	
Peanut	Brazil	AFB1	58	45.30	Hoeltz et al, 2012 [22]
Peanut	Malaysia	AFB1	9	15.54	Hong et al, 2010 [23]
Peanut (raw)	Korea	AFT	4	0.20	Hyang Sook Chun
		AFB1	4	0.20	et al, 2007 [24]
Peanut	South Korea	AFB1	27	4.07	Hyun ee ok et al, 2007 [24]
Peanuts with	Italy	AFB1	67	42.06	Imperato et al, 2011 [25]
shell		AFT	67	45.36	
Peanut	Morocco	AFB1	20	0.17	Juan et al, 2008 [26]
		AFT	20	0.30	
Peanut	Congo	AFB1	60	229.07	Kamika et al, 2011 [27]
Peanut	Congo	AFB1	20	97.38	Kamika et al, 2014 [28]
		AFT	20	197.11	
Peanut	South Africa	AFB1	20	6.90	
		AFT	20	13.59	
Peanut	Malaysia	AFB1	11	4.25	Kasa R.N. Reddy et al, 2011 [29]
Ground nuts	South-western Uganda	AFT	3	11.50	Kitya et al, 2010 [30]
Peanut	Brazil	AFT	22	27.50	Kujbida et al, 2019 [31]
Ground nuts	Ghana	AFB1	120	18.20	Kwabena Asare Bediako et al, 2019
		AFT	120	25.00	[32]
Peanut	Island	AFT	22	4.00	Lovelace et al, 1989 [33]
Peanuts with shell	Pakistan	AFT	10	5.10	Luttfullah et al, 2011 [34]

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Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Peanuts without shell		AFT	10	5.20	
Peanuts with shells	Pakistan	AFB1	20	5.87	Masood et al, 2015 [35]
		AFT	20	6.40	
Peanuts without shells		AFB1	20	6.34	
		AFT	20	7.89	
Whole peanut	Taiwan	AFT	2	1.50	Ming-Tzai Chen et al, 2016 [36]
Ground nuts	Bangladesh	AFB1	5	93.10	Monika Roy et al, 2013 [37]
Peanut	Saudi Arabia	AFB1	5	0.60	Moussa Tarek et al, 2017 [38]
		AFT	5	3.10	
Ground nuts		AFB1	10	13.30	
		AFT	10	20.40	
Ground nuts	Yemen	AFT	89	8.88	Murshed et al, 2019 [39]
Peanut	Thailand	AFB1	9	0.85	Natthasit Tansakul et al, 2013 [40]
		AFT	9	1.43	
Peanut	Cameroon	AFT	16	6.50	Njobeh et al, 2010 [41]
Ground nuts	Zambia	AFB1	45	9.82	Njoroge et al, 2017 [42]
		AFB1	92	189.52	
		AFB1	20	4.62	
Peanut	Malaysia	AFB1	22	5.00	Norhayati et al, 1999 [43]
		AFT	22	79.00	
		AFB1	22	48.00	
		AFT	22	72.00	
Peanut	Malaysia	AFB1	87	56.00	Norlia et al, 2018 [44]
		AFT	87	60.70	
Peanut	Brazil	AFB1	19	6.02	Oliveira et al, 2009 [45]
		AFT	19	12.88	
Peanut	Iran	AFT	23	19.88	Ostadrahimi et al, 2014 [46]
Ground nuts	Nigeria	AFB1	25	117.80	Oyedele et al, 2017 [47]
		AFT	33	216.10	
Peanut	Taiwan	AFB1	60	32.00	Robin et al, 1997 [48]
		AFB1	60	26.00	
		AFB1	60	12.00	
		AFT	60	150.00	
		AFT	60	160.00	
		AFT	60	32.00	
Peanut	Spain	AFB1	1	120.00	Sanchis et al, 1986 [49]
Peanut	Côte d'Ivoire	AFB1	10	4.80	Sangare-Tigori et al, 2006 [50]
Peanut	Iran	AFB1	6	nd	Siahi Shadbad et al, 2012 [51]
		AFT	6	nd	

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Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Peanut	Korea	AFT	1	7.97	Su Jeong Choi et al, 2011 [52]
		AFB1	1	6.43	
Peanut	Uganda	AFT	33	180.70	Sylvia Angubua Baluka et al, 2017
		AFB1	33	103.10	[53]
Raw peanut	China	AFB1	110	2.06	Xiaoxia Ding et al, 2015 [54]
			141	3.15	
			279	5.80	
			159	6.72	
			222	13.20	
			24	10.15	
Peanut	Taiwan	AFT	20	14.90	Ying-Chun Chen et al, 2013 [55]
		AFB1	20	1.56	
Peanuts with shells	Japan	AFT	30	nd	Yoshiko Sugita-Konishi et al, 2006
		AFB1	30	nd	[56]
Peanuts without shells		AFT	30	nd	
		AFB1	30	nd	
Raw peanuts in shells	Pakistan	AFT	22	6.40	Zafar Iqbal et al, 2013 [57]
Raw peanuts without shells		AFT	29	9.60	
Peanuts with shell		AFB1	14	5.50	
		AFT	14	6.10	
Peanuts without shell		AFB1	11	5.90	
		AFT	11	7.30	

Supplementary Table 2. The aflatoxin concentration in pistachio from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Pistachio	Saudi Arabia	AFB1	1	0.06	AlFaris et al, 2020 [6]
		AFB1	1	nd	
Pistachio	Iran	AFB1	1921	2.18	Ali Dini et al, 2013 [58]
		AFT	1927	2.42	
Pistachio	Pakistan	AFT	126	1.18	Asif Asghar et al, 2017 [12]
Pistachio	Spain	AFB1	6	nd	Blesa et al, 2004 [13]
		AFB1	6	nd	
Pistachio	Iran	AFB1	3,699	5.90	Cheraghali et al, 2007 [59]
		AFT	2,852	7.30	
Pistachio	Cyprus	AFB1	105	8.20	Christofidou et al, 2015 [16]

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Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Pistachio	Saudi Arabia	AFT	53	16.60	El tawila et al, 2013 [17]
Pistachio	Spain	AFT	50	21.40	Fernane et al, 2010 [60]
Pistachio	Turkey	AFB1	151	4.55	Hepsag et al, 2014 [21]
		AFT	151	4.95	
Pistachio	Korea	AFT	4	3.41	Hyang Sook Chun et al, 2007 [24]
		AFB1	4	3.36	
Pistachio	South Korea	AFB1	15	16.22	Hyun ee ok et al, 2007 [24]
Pistachios without shell	Italy	AFB1	5	1.29	Imperato et al, 2011 [25]
		AFT	5	1.47	
Pistachio	Morocco	AFB1	20	158.00	Juan et al, 2008 [26]
		AFT	20	163.00	
Pistachio	Japan	AFB1	7	161.80	Kazuo Saito et al, 1984 [61]
Pistachio	Malaysia	AFT	4	nd	Leong et al, 2011 [62]
Pistachios with shell	Pakistan	AFT	10	2.10	Luttfullah et al, 2011 [34]
Pistachios without shell		AFT	10	6.34	
Pistachios with shell	Pakistan	AFB1	20	5.96	Masood et al, 2015 [35]
		AFT	20	6.80	
Pistachios without shell		AFB1	20	6.47	
		AFT	20	7.53	
Pistachio	Taiwan	AFT	2	245.60	Ming-Tzai Chen et al, 2016 [36]
		AFB1	2	233.60	
Pistachio	Bahrain	AFB1	3	24.90	Musaiger et al, 2008 [63]
		AFT	3	27.30	
Pistachio	Iran	AFT	43	3.03	Ostadrahimi et al, 2014 [46]
Pistachio	Iran	AFB1	95	185.89	Sarhang pour et al, 2009 [64]
		AFT	95	215.05	
Pistachio	Korea	AFB1	7	nd	Su Jeong Choi et al, 2011 [52]
		AFT	7	nd	
Pistachios with shell	Pakistan	AFB1	15	4.20	Zafar Iqbal et al, 2018 [65]
		AFT	15	4.90	
Pistachios without shell		AFB1	16	5.80	
		AFT	16	7.10	

Supplementary Table 3. The aflatoxin concentration in almond from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Almond	Pakistan	AFT	10	1.22	Asif Asghar et al, 2017 [12]
Almond	Cyprus	AFB1	5	32.90	Christofidou et al, 2015 [16]
Almond	Saudi Arabia	AFB1	1	0.47	AlFaris et al, 2020 [6]
			3	nd	
			1	12.00	
			1	0.56	
White			1	0.77	
Almonds			1	nd	
Raw	Spain	AFB1	7	nd	Blesa et al, 2004 [13]
Almond		AFB1	7	nd	
Almond	Saudi Arabia	AFT	53	3.50	El tawila et al, 2013 [17]
Almond	Turkey	AFT	3	7.40	Gürses et al, 2006 [20]
Almond	Turkey	AFB1	30	0.06	Kani et al, 2019 [66]
		AFT	30	0.10	
Almonds with shells	Pakistan	AFT	10	nd	Luttfullah et al, 2011 [34]
Almonds without shells		AFT	10	2.13	
Almond	Pakistan	AFB1	20	4.64	Masood et al, 2015 [35]
		AFT	20	4.97	
Almond	Saudi Arabia	AFB1	4	nd	Moussa Tarek et al, 2017 [38]
		AFT	4	0.90	
In-shell	USA	AFB1	10	7.32	Schade et al, 1975 [67]
Almond		AFT	10	14.75	
Almond	Iran	AFB1	35	nd	Siahi Shadbad et al, 2012 [51]
		AFT	35	nd	
Almond	Korea	AFB1	20	nd	Su Jeong Choi et al, 2011 [52]
		AFT	20	nd	
Almond	USA	AFT	100	0.67	Thomas F. Schatzki et al, 1996 [68]
Almond	China	AFT	8	1.16	Wang Yujiao et al, 2018 [69]
Almonds with shells	Pakistan	AFB1	14	3.20	Zafar Iqbal et al, 2018 [65]
		AFT	14	4.50	
Almonds without shells		AFB1	15	4.90	
		AFT	15	6.20	

Supplementary Table 4. The aflatoxin concentration in Hazelnut from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Hazelnut	Turkey	AFB1	50	1.72	Aksoy et al, 2010 [70]
Hazelnut	Italy	AFT	35	0.64	Ambra Prelle et al, 2012 [71]
Hazelnut	Spain	AFB1	2	0.61	Blesa et al, 2004 [13]
		AFB1	2	0.42	
Hazelnut	Italy	AFT	1	124.00	Diella et al, 2018 [72]
		AFB1	1	56.10	
Hazelnut	Saudi Arabia	AFT	28	2.50	El tawila et al, 2013 [17]
Hazelnut	Turkey	AFT	9	34.40	Gürses et al, 2006 [20]
Hazelnuts without shell	Italy	AFB1	32	0.20	Imperato et al, 2011 [25]
		AFT	32	0.51	
Hazelnut	Turkey	AFB1	50	4.23	Kabak et al, 2016 [73]
		AFT	50	4.81	
Hazelnut	China	AFT	1	2.10	Wang Yujiao et al, 2018 [69]

Supplementary Table 5. The aflatoxin concentration in Walnut from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Walnuts	Saudi Arabia	AFB1	3	nd	AlFaris et al, 2020 [6]
Walnuts	Pakistan	AFT	8	1.08	Asif Asghar et al, 2017 [12]
Walnuts	Spain	AFB1	1	nd	Blesa et al, 2004 [13]
		AFB1	1	nd	
Raw		AFB1	4	nd	
walnut		AFB1	4	nd	
Walnuts	Cyprus	AFB1	33	nd	Christofidou et al, 2015 [16]
Walnuts	Saudi Arabia	AFT	28	3.40	El tawila et al, 2013 [17]
Walnuts	Turkey	AFT	6	22.10	Gürses et al, 2006 [20]
Walnuts	Korea	AFT	12	nd	Hyang Sook Chun et al, 2007 [24]
		AFB1	12	nd	
Walnuts	South Korea	AFB1	19	nd	Hyun ee ok et al, 2007 [24]
Walnuts	Iran	AFB1	35	9.00	Imani Nejad et al, 2012 [74]
		AFT	35	11.68	
Walnuts	Morocco	AFB1	20	360.00	Juan et al, 2008 [26]
		AFT	20	730.00	
Walnuts with shells	Turkey	AFB1	35	0.01	Kabak et al, 2014 [75]
		AFT	35	0.01	
Walnuts without shells		AFB1	50	0.16	
		AFT	50	0.20	
Walnuts	Malaysia	AFT	3	nd	Leong et al, 2011 [62]

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Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Walnuts with shells	Pakistan	AFT	10	6.45	Luttfullah et al, 2011 [34]
Walnuts without shells		AFT	10	3.43	
Walnuts	Pakistan	AFB1	20	3.22	Masood et al, 2015 [35]
with shell		AFT	20	5.82	
Walnuts		AFB1	20	4.80	
without shell		AFT	20	5.43	
Walnuts	Saudi Arabia	AFB1	4	nd	Moussa Tarek et al, 2017 [38]
		AFT	4	0.70	
Walnuts	Iran	AFT	43	14.40	Ostadrahimi et al, 2014 [46]
Walnuts	Turkey	AFT	16	1.68	Özturk Yilmaz et al, 2017 [76]
without shell		AFB1	5	0.86	
Walnuts	Korea	AFB1	17	nd	Su Jeong Choi et al, 2011 [52]
		AFT	17	nd	
Walnuts	China	AFT	6	0.86	Wang Yujiao et al, 2018 [69]

Supplementary Table 6. The aflatoxin concentration in Brazil nut from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Brazil nut	Brazil	AFT	67	36.90	Andrade et al, 2013 [9]
In shell	Brazil	AFT	26	6.10	Ariane et al, 2007 [59]
brazil nut			26	3.80	
			26	1.50	
			26	2.50	
Shelled			26	4.50	
Brazil nut			26	3.00	
			26	1.50	
			26	3.00	
Brazil nut	Cyprus	AFB1	1	3.00	Christofidou et al, 2015 [16]
Brazil nut	Brazil	AFB1	51	3.71	Iamanaka et al, 2014 [77]
		AFT	51	0.98	
Brazil nut	Malaysia	AFT	3	0.88	Leong et al, 2011 [62]

Supplementary Table 7. The aflatoxin concentration in other nuts from included studies.

Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Cashew nuts	Nigeria	AFT	27	4.90	Adetunji et al, 2018 [3]
Nuts	Brazil	AFT	82	8.30	Andrade et al, 2013 [9]
Nuts	Greece	AFT	13	4.83	Batrinou et al, 2020 [78]
Cashew nuts	Spain	AFB1	1	nd	Blesa et al, 2004 [13]
			1	nd	
			1	nd	
			1	nd	
Macadamia			1	nd	
nut			1	nd	
Nuts Cocktail			1	0.37	
			1	0.29	
Pinhol			2	0.09	
			2	nd	
Cashew nuts	Cyprus	AFB1	14	nd	Christofidou et al, 2015 [16]
			19	nd	
Nuts	Poland	AFB1	15	0.13	Czerwiecki et al, 2006 [79]
		AFT	18	0.19	
Cashew nuts	Saudi Arabia	AFT	53	1.60	El tawila et al, 2013 [17]
Assorted nuts	Korea	AFT	1	7.89	Hyang Sook Chun et al, 2007 [24]
		AFB1	1	6.68	
Nuts	Malaysia	AFB1	2	0.87	Kasa R.N. Reddy et al, 2011 [29]
Sunflower			6	2.55	
Cashew nuts	Brazil	AFT	12	3.30	Kujbida et al, 2019 [31]
Cashew nuts	Pakistan	AFB1	20	3.11	Masood et al, 2015 [35]
		AFT	20	3.11	
Nuts	Taiwan	AFT	7	35.40	Ming-Tzai Chen et al, 2016 [36]
Betelnut	Bangladesh	AFB1	5	30.60	Monika Roy et al, 2013 [37]
Nuts	Saudi Arabia	AFB1	6	2.60	Moussa Tarek et al, 2017 [38]
		AFT	6	8.80	
Nuts	Egyptian	AFB1	17	24.00	Mustafa I. Selim et al, 1996 [80]
Tigernuts	Spain	AFT	3	8.67	Natividad et al, 2010 [81]
		AFB1	3	2.40	
Betelnut	India	AFB1	12	94.17	Raisuddin et al, 1991 [82]
Cashew nuts	Iran	AFB1	2	18.30	Siahi Shadbad et al, 2012 [51]
		AFT	2	21.00	
Cashew nuts	Korea	AFB1	12	nd	Su Jeong Choi et al, 2011 [52]
		AFT	12	nd	
Macadamia		AFB1	2	nd	
nut		AFT	2	nd	
Pecan		AFB1	4	nd	
		AFT	4	nd	

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Nut sample	Sampling country	Aflatoxin	Number of samples	Mean concentration	Author
Chilgoza pine nut	India	AFT	27	493.91	Sumedha Sharma et al, 2015 [83]
Raw areca nuts	Durban	AFT	10	8.90	Van der bijl et al, 1996 [84]
Sliced raw		AFB1	10	5.00	
areca nut		AFB1	10	12.40	
		AFB1	10	15.20	
Cashew nuts	China	AFT	2	20.03	Wang Yujiao et al, 2018 [69]
Nuts		AFB1	5	9.30	
Pine nuts		AFT	20	nd	
Cashew nuts	Pakistan	AFB1	18	3.75	Zafar Iqbal et al, 2018 [65]
with shell		AFT	18	4.30	
Cashew nuts		AFB1	11	4.50	
without shell		AFT	11	5.90	

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