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Mycobiota associated with baby food products imported into Uganda with special reference to aflatoxigenic aspergilli and aflatoxins

MADY A. ISMAIL *, HANNINGTON K. TALIGOOLA and REBBECCA NAKAMYA

Department of Botany, Faculty of Science, Makerere University, P. O. Box 7062, Kampala, Uganda
*corresponding author; madyismail@yahoo.com

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Five baby food products imported into Uganda were collected from different shops and investigated for contamination by fungi and aflatoxins. Forty-two species belonging to 21 genera in addition to some unidentified fungi were recovered on dichloran rose bengal chloramphenicol agar. Cornflakes followed by Cerelac were the most heavily contaminated products while Heinz mixed cereal was the least. *Cladosporium sphaerospermum*, *Fusarium tricinctum* and *Penicillium oxalicum* were the most predominant fungi. On the other hand, using *Aspergillus flavus/parasiticus* agar, 34 % of the samples were positive for aflatoxigenic aspergilli. Aflatoxigenic aspergilli constituted 78.8 % of all aspergilli and 4.9 % of all contaminating fungi. Samples from all products were contaminated with aflatoxigenic aspergilli, but samples of Cerelac were the most, while those of Porridge oats were the least. Aflatoxin analysis of food samples revealed that 9 out of 13 analysed samples were contaminated with aflatoxins in the range of 1–10 ppb (6 samples) and 11–20 ppb (3 samples). Only samples of Cerelac were aflatoxin–free, although aflatoxigenic aspergilli were detected in some samples. It was noted that samples of Cerelac had the least moisture content compared to the other products. Contaminated foods constitute a health hazard to human consumption. These foods, especially those for babies, must therefore be examined at regular intervals in order to assess their hygienic quality.

Key words: mycobiota, aflatoxigenic aspergilli, aflatoxins, imported baby foods.

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Pět druhů dětských potravin importovaných do Ugandy bylo studováno s ohledem na jejich kontaminaci mikromycety a aflatoxiny. Bylo zjištěno celkem 42 druhů mikromycetů patřících do 21 rodů. Kukuřičné vločky následované produktem Cerelac byly nejvíce kontaminovány, nejméně pak produkt zvaný Heinz mixed cereal. Dominovaly druhy *Cladosporium sphaerospermum*, *Fusarium tricinctum* a *Penicillium oxalicum*. Při použití speciálního agaru bylo 34 % vzorků pozitivní na přítomnost aflatoxinogenních druhů rodu *Aspergillus*, které představovaly 78.8 % všech druhů tohoto rodu a 4.9 % všech zjištěných mikromycetů. Všechny produkty obsahovaly aflatoxinogenní druhy rodu *Aspergillus*, ale kontaminace jednotlivých druhů potravin byla různě velká. Vzhledem ke zdravotnímu riziku kontaminovaných potravin, zejména dětských, bude nutná jejich pravidelná kontrola.

INTRODUCTION

Moulds are widely distributed in nature and are common contaminants of agricultural commodities, foods beverages and feeds (Gourama and Bullerman 1995). They probably contaminate and spoil more foods than any other group of microorganisms. They render contaminated foods not only unpalatable, but also unsafe for consumption by producing mycotoxins (Munimbazi and Bullerman 1996). The presence of aflatoxins in foods is of great concern since they are of the most active ingested carcinogens (Pitt and Hocking 1997).

Baby foods rich in carbohydrates and proteins are being produced from cereal and leguminous foods/grains. The manufacture of baby foods is based on dried cereals like maize, rice, millet, sorghum, wheat and oats. It involves mixing the cereal flour with various additional ingredients such as powders of soya beans, dried fish or fruits.

Many reports have been published earlier at different localities of the world on the microbiological quality of baby foods (Jarchovská et al. 1980, Schwab et al. 1982, Moustafa et al. 1984, Abdel-Sater and Ismail 1993, Al-Ashmawy et al. 1993, Zohri et al. 1995, Munimbazi and Bullerman 1996) or their ingredients such as wheat (Aran and Eke 1987, Mills et al. 1995), milk powder (Jesenská and Hrdinová 1981, Ismail and Saad 1997), rice (Pitt et al. 1994, Taligoola et al. 2004), maize (Pitt et al. 1993, Ismail et al. 2003), millet (Mishra and Daradhiyar 1991), barley (El-Maghraby 1989), oats (Flannigan 1970) and sorghum (Pitt et al. 1994).

In Uganda, knowledge about fungi on foods manufactured from these components, especially those which come from abroad, is limited. Hence, this work was designed to survey the fungi associated with imported baby foods and their levels of mycotoxins.

MATERIALS AND METHODS

Fifty samples from five different baby food products imported into Uganda (10 tins or packets each) were randomly bought from different shops in Kampala during the years 1999 and 2000. Each of these baby foods contained at least one or more cereal products (Tab. 1). These samples were collected during the stage of marketing and once brought to the laboratory, they were mycologically analysed.

Determination of moisture content

Three sub-samples of 50 g each were taken from each food sample and put on an aluminium foil dish. These were dried in an oven at 110 °C for 24 hours, and reweighed (Magan and Lacey 1985, Pitt and Hocking 1997). The moisture content of each sample was expressed as the average percentage of weight loss of the three replicates.

Tab. 1. Imported baby food products, their main cereal components and country of origin.

No.	Product	Main cereal components	Country of origin
1	Heinz mixed cereals	Corn flour, oats flour, malted barley flour	Canada
2	Cerelac	Wheat flour	Kenya
3	Corn flakes	Maize flour, malt flavouring	England
4	Weetabix	Whole wheat flour, malt extract	England
5	Porridge oats	Rolled roasted oats	Kenya

Mycological analysis

The dilution-plate method was used for enumeration and isolation of fungi from the baby food samples. All samples were analysed on plates of dichloran rose bengal chloramphenicol agar, DRBC (King et al. 1979), and *Aspergillus flavus/parasiticus* agar, AFPA (Pitt et al. 1983). Four plates for each medium were used for each sample. The inoculated DRBC plates were incubated at room temperature (25–27 °C) in a day-and-night cycle of light conditions for 7–10 days. The growing fungi were enumerated, isolated and identified. The inoculated plates with AFPA medium were incubated for 42 hours at 30 °C (Pitt et al. 1983, Pitt and Hocking 1997). After incubation the reverse of the Petri dishes was examined for a bright yellow/orange coloration (Pitt and Hocking 1997). The identification of the aflatoxigenic aspergilli and other moulds was confirmed on the basis of their macroscopic and microscopic features using the keys by Raper and Fennell (1965), Booth (1971), Ellis (1971), Pitt (1979) and Pitt and Hocking (1997). The counts of fungi on both media were expressed as CFU/g (colony forming units per gram baby food).

Aflatoxin analysis

A semiquantitative method for the determination of the total amount of aflatoxins in food samples was applied, whereby a commercial immunological test kit, aflascan (from Rhône–Diagnostics and Technologies Ltd., Glasgow, Scotland), was used. The procedure outlined in the aflascan and also described by Ismail et al. (2003) was followed. Thirteen out of the fifty mycologically investigated samples were randomly chosen for aflatoxin analysis: 3 from each of Heinz mixed cereal, Weetabix, Porridge oats and 2 from each of Cerelac and Cornflakes. All contents of two packets or tins were thoroughly mixed, then a 50 g sub-sample was blended with 4 g of sodium chloride (NaCl) and 250 ml of 60 % methanol. The extract was diluted with 250 ml of distilled water and then filtered using Whatman filter paper No. 4. Twenty five to fifty ml of the filtrate was collected; 10 ml of the filtrate was then passed through the immunoaffinity column so that the aflatoxins were adsorbed by the antibodies. The column was then washed twice with distilled water. Pure methanol was passed into the column to release the aflatoxins after which it was collected in a test tube. Water and chloroform were added (1 ml each) to the aflatoxin eluate and shaken gently, then left to stand. The bottom chloroform layer was pipetted out and then passed through a florisil tip. The florisil tip was then viewed under 366 nm UV light and the fluorescence of the toxins was compared with a standard comparator card (a component of the aflascan) with semi-quantitative values to obtain the range of total aflatoxin contamination in the extracts in ppb (Bullerman 1979) .

Statistical analysis

Analysis of variance (ANOVA) was used to analyse the data (Steel and Torrie 1980).

RESULTS AND DISCUSSION

The moisture contents of the food products varied widely, between 3.1 (the least being recorded in Cerelac) and 10.8 % (in Porridge oats) (Tab. 2).

Two different agar media were used for enumeration and isolation of fungi from the baby food products investigated. The general isolation medium, dichloran rose bengal chloramphenicol agar, DRBC (King et al. 1979) is recommended for moulds that are significant in food spoilage. The other medium, *Aspergillus flavus/parasiticus* agar (AFPA) is recommended for selective isolation of aflatoxigenic *Aspergillus* species from such foods (Pitt et al. 1983).

Tab. 2. Colony forming units (CFU/g baby food) and percentage frequency (F %, out of 10 samples analysed) of the most common fungi, number of genera and species, and moisture contents of the five imported baby food products investigated on DRBC.

Fungi	Heinz mixed cereal		Cerelac		Corn flakes		Weetabix		Porridge oats	
	CFU	F %	CFU	F %	CFU	F %	CFU	F %	CFU	F %
Aspergillus flavus	40	30	2200	60	10	10	25	20	5	10
Aflatoxigenic aspergilli on AFPA	85	30	1125	80	20	10	165	30	10	20
Cladosporium sphaerospermum	35	40	875	90	220	80	175	60	50	40
Fusarium tricinctum					1550	30	1425	50	265	50
Penicillium oxalicum	30	10	2425	60			35	20	90	60
Yeasts	25	40			7500	40			3980	40
CFU of all fungi	670	100	9750	100	9840	100	1970	100	4700	100
No. of genera (21)	9		6		7		10		12	
No. of species (42)	14		17		11		18		23	
Moisture content [mean (minimum –maximum)]	10.1 (9.8–10.6)		3.1 (2.8–3.6)		9.3 (9.0–9.4)		10.6 (10.2–11.0)		10.8 (10.0–11.8)	

Fungi recovered on dichloran rose bengal chloramphenicol agar (DRBC)

Imported baby foods plated on dichloran rose bengal chloramphenicol medium (DRBC) yielded 42 species belonging to 21 genera in addition to some unidentified fungi. The broadest spectrum of genera and species was recorded in Porridge oats (12 genera and 23 species) followed by Weetabix (10, 18), Heinz mixed cereal (9, 14), Cornflakes (7, 11) and Cerelac (6, 17). *Cladosporium*, *Fusarium* and *Penicillium* were the predominant genera (Tabs. 2, 3). El-Maghraby (1989) found that *Aspergillus*, *Penicillium*, *Fusarium* and *Cladosporium* were the most common genera in wheat, barley, corn and sorghum.

Cladosporium (2 species) was the most predominant genus. It was recovered from 72 % of the samples, accounting for 5.5 % of the total CFU. The two species were *C. sphaerospermum* and *C. cladosporioides*, however the former constituted the majority of *Cladosporium* CFU (91.3 %). The most heavily contaminated food products with this species were Cerelac, followed by Cornflakes and Weetabix, while Heinz mixed cereal and Porridge oats were the least contaminated. In agreement with our results for Cerelac (product of wheat and milk), both species were also reported in high frequency in the Egyptian foodstuff Kishk (a product of wheat and sour milk) (Ismail 1993). However, *Cladosporium* was found in low frequency in milk powder (Ismail and Saad 1997), baby foods (a product of milk and cereal flour) (Al-Ashmawy 1993), and in corn snacks (products of corn flour) (Zohri et al. 1995). On the other hand, both species have been isolated in high frequency from barley (Flannigan 1969, Abdel-Kader et al. 1979) and wheat grains (El-Maghraby 1989).

Fusarium was the second most common genus recovered in the five food products. It contaminated 62 % of the samples, however it constituted a higher number of CFU (25.6 % of the total) than in *Cladosporium.* It was found to contaminate most heavily Cerelac (a product of wheat and milk), Cornflakes (corn product) and Weetabix (wheat product), while its lowest CFU were found in Porridge oats and Heinz mixed cereals (products of barley and wheat). These results are in disagreement with earlier reports on other food products such as the Egyptian foodstuff Kishk (of wheat and milk) (Ismail 1993), biscuits (of wheat and milk) (Abdel-Sater and Ismail 1993), baby foods (of milk and different cereals) (Al-Ashmawy et al. 1993), corn flakes (Zohri et al. 1995) and milk powder (Ismail and Saad 1997). However, *Fusarium* was reported to be frequent in barley, wheat and oats (Flannigan 1970, El-Kady et al. 1982, Lacey 1988). It was represented by 6 species, of which *F. tricinctum* and *F. verticillioides* (= *F. moniliforme*) being the most common, while the other four (*F. solani*, *F. lateritium*, *F. oxysporum* and *F. proliferatum*) were less frequent. The two former species were also reported to be present in high frequency in maize meal by Marasas and Smalley (1972). *F. verticillioides* was reported to be the cause of severe deterioration in wheat and corn (Moubasher et al. 1972). It was isolated from cereals such as corn, barley, sorghum and wheat (El-Kady et al. 1982, El-Maghraby 1989, Ismail et al. 2003). *F. verticillioides* is a well known producer of moniliformin and fumonisins. Moniliformin is toxic and produces intestinal haemorrhage and death in mice, rats, and broiler chickens (Abbas and Bosch 1990). *Fusarium* species were isolated in smaller numbers and produced lesser damage to wheat grains (Assawah and Elarosi 1960, Abdalla et al. 1973). *Fusarium* species are field fungi and they contaminate most of the cereals in the field but the spores can survive when conditions are favourable. These conditions basically include moisture content, temperature and storage period. Being field fungi, they require higher moisture contents that amount to 24–25 % and can be eliminated by storage. Christensen and Kaufmann (1965) and Moubasher et al. (1972) reported that *Fusarium* does not survive long in grains especially if the moisture content of grains is high enough to permit invasion by storage fungi.

Tab. 3. Incidence of fungi from imported baby food products on dichloran rose bengal chloramphenicol agar (DRBC).

Genera and species	CFU	CFU %	F %	OR	Source
Aspergillus	2915	10.80	46	M	1, 2, 3, 4, 5
A. candidus	15	0.06	2	R	3
A. flavus	2280	8.46	26	M	1, 2, 3, 4, 5
A. niger	310	1.15	12	R	1, 2, 4
A. ochraceus	20	0.07	4	R	3
A. oryzae	75	0.27	2	R	2
A. parasiticus	150	0.55	4	R	2
A. penicillioides	25	0.09	2	R	5
A. restrictus	15	0.05	6	R	4, 5
A. ustus	25	0.09	2	R	2
Chrysosporium farinicola	45	0.15	6	R	4
Cladosporium	1485	5.51	72	H	1, 2, 3, 4, 5
C. cladosporioides	130	0.48	50	H	1, 2, 3, 4, 5
C. sphaerospermum	1355	5.03	62	H	1, 2, 3, 4, 5
Cochliobolus pallescens	5	0.02	2	R	5
Colletotrichum gloeosporioides	25	0.09	2	R	2
Curvularia	15	0.05	6	R	1, 5
C. ovoidea	10	0.03	4	R	1, 5
C. trifolii	5	0.02	2	R	1
Eurotium	125	0.46	6	L	4, 5
E. chevalieri	5	0.02	2	R	5
E. cristatum	110	0.41	14	L	3, 5
E. repens	10	0.03	4	R	4, 5
Geotrichum candidum	175	0.65	10	R	2, 4
Gliomastix subiculosa	5	0.02	2	R	4
Fusarium	6895	25.60	62	H	1, 2, 3, 4, 5
F. lateritium	250	0.93	10	R	2
F. oxysporum	5	0.02	2	R	5
F. proliferatum	2570	9.54	8	R	1, 2
F. solani	645	2.39	24	L	1, 2, 3, 5
F. tricinctum	324	12.03	26	M	3, 4, 5
F. verticillioides	185	6.86	20	L	2, 3, 4, 5
Lasiodiplodia theobromae	10	0.03	4	R	3, 4
Monographella nivalis	10	0.03	2	R	5
Monascus ruber	5	0.02	2	R	4
Mucor plumbeus	10	0.03	2	R	1
Paecilomyces variotii	5	0.02	2	R	5
Penicillium	3555	13.19	50	H	1, 2, 3, 4, 5
P. aurantiogriseum	25	0.09	2	R	2
P. camemberti	25	0.09	8	R	5

Genera and species	CFU	CFU %	F %	OR	Source
P. corylophilum	15	0.05	6	R	3, 4, 5
P. citrinum	365	1.35	24	L	2, 3, 4, 5
P. oxalicum	2825	10.49	3	M	1, 2, 4, 5
P. viridicatum	275	1.02	8	R	1, 2
Phoma sp.	5	0.02	2	R	1
Rhizopus stolonifer	75	0.27	6	R	1
Wallemia sebi	5	0.2	2	R	5
Yeasts	11505	42.22	3	M	1, 3, 5
Brettanomyces bruxellensis	3750	13.92	6	R	1, 3, 5
Rhodotorula mucilaginosa	1160	4.37	10	R	1, 3, 5
Yeasts (white)	6595	24.46	20	L	1, 3, 5
Other unidentified fungi	65	0.24	14	L	2, 3, 5
All fungi	26930	100	100	H	1, 2, 3, 4, 5

CFU = colony forming units (number / g baby food product in 50 samples).
CFU % = Percentage of colony forming units (calculated per CFU of all fungi).
F % = Percentage frequency (number of samples/50).
OR = Occurrence remarks; High (H) = 50–100 %, Moderate (M) = 25–49 %, Low (L) = 13–24 % and Rare (R) = 0–12 %.
Source: 1 = Heinz mixed cereal, 2 = Cerelac, 3 = Cornflakes, 4 = Weetabix and 5 = Porridge oats.

Penicillium (6 species) came third in incidence (50 % of the samples), but ranked second in CFU percentage (13.2 % of total). It was isolated from all products and contaminated Cerelac most heavily and Cornflakes the least. This finding, whereby Cerelac, a product of wheat, was heavily contaminated with *Penicillium*, is in agreement with earlier reports on Kishk, a wheat product (Ismail 1993), biscuits, a product of wheat and milk (Abdel-Sater and Ismail 1993), baby foods, products of milk and cereals (Al-Ashmawy et al. 1993), Cornsnacks, products of cornflour (Zohri et al. 1995) and milk powder (Ismail and Saad 1997). Similarly, penicillia were isolated from wheat (Moubasher et al. 1972, El-Maghraby 1989). *P. oxalicum* and *P. citrinum* were the most commonly isolated species. *P. oxalicum* was also reported from biscuits (Abdel-Sater and Ismail 1993), from wheat and corn (Moubasher et al. 1972, Ismail et al. 2003). However, it was infrequently isolated from cornsnacks (Zohri et al. 1995). *P. citrinum* was frequently isolated from wheat and corn (Mislivec and Tuite 1970, Moubasher et al. 1972). *P. citrinum* is the main producer of the citrinin mycotoxin, while *P. oxalicum* produces secalonic acid D as the major metabolite. Both mycotoxins have significant animal toxicity (Ciegler et al. 1980). The other 4 species (*P. camemberti*, *P. corylophilum* and the nephrotoxigenic species *P. aurantiogriseum* and *P. viridicatum*) were rarely encountered.

Aspergillus (9 species) came fourth and was encountered in 46 % of the samples accounting for 10.8 % of the total CFU. It was found to contaminate most heavily Cerelac (a wheat product), Heinz mixed (a barley product) and Weetabix (a wheat product). Earlier studies reported *Aspergillus* to be common in biscuits and Kishk, products of wheat and milk (Abdel-Sater and Ismail 1993, Ismail 1993), baby foods, products of milk and cereals (Al-Ashmawy et al. 1993) and milk powder (Ismail and Saad 1997). Similarly, aspergilli were reported from different cereal grains (Assawah and Elarosi 1960, Flannigan 1970, Moubasher et al. 1972, Lacey 1988, El-Maghraby 1989, Ismail et al. 2003, Taligoola et al. 2004). *Aspergillus flavus* was the most common species occurring in 26 % of the samples, accounting for 78.2 % of *Aspergillus* CFU and 8.5 % of the total CFU. It was found to contaminate Cerelac most, followed by Heinz mixed cereal and its lowest level was recorded in Porridge oats and Cornflakes. The incidence of *A. flavus* in high numbers in Cerelac, a product of wheat and milk, is in agreement with earlier reports on Kishk, a product of wheat and milk (Ismail 1993). *A. flavus* was also the most frequently isolated fungus from wheat (Abdalla et al. 1973) as well as cereal grains in Ethiopia (Abate and Gashe 1985) and Uganda (Ismail et al. 2003, Taligoola et al. 2004). The other eight *Aspergillus* species were isolated in low frequency: *A. candidus*, *A. niger*, *A. ochraceus*, *A. oryzae*, *A. parasiticus*, *A. penicillioides*, *A. restrictus* and *A. ustus*. However, *A. restrictus* was reported to be a common cause of deterioration in all kinds of stored grains and seeds (Christensen and Kaufman 1965).

Yeasts were isolated in moderate amounts, yet accounted for 42.2 % of the total counts. The most common yeasts were *Brettanomyces bruxellensis*, *Rhodotorula mucilaginosa* and white yeasts. Yeasts were previously isolated frequently from corn snacks (Zohri et al. 1995).

The remaining 15 fungal species were infrequently isolated, accounting collectively for a small proportion of the CFU (1.6 %): *Cochliobolus pallescens*, *Curvularia trifolii*, *Geotrichum candidum*, *Eurotium chevalieri*, *E. cristatum*, *E. repens*, *Gliomastix subiculosa*, *Lasiodiplodia theobromae*, *Monographella nivalis*, *Monascus ruber*, *Mucor plumbeus*, *Paecilomyces variotii*, *Phoma* sp., *Rhizopus stolonifer* and *Wallemia sebi*. Some of these were also isolated in moderate or low frequency from different cereal grains all over the world (Pitt and Hocking 1997).

Results from the Anova test at 5 % significance level showed that $F_{test} = 3.13 > F_{critical} = 0.0659$ at df = 3, which reveals significant differences in CFU of the different genera recorded from the imported baby foods on DRBC. Similarly, the Anova test of significance revealed that there were statistically significant differences in the CFU of a particular fungal genus recovered from the different 5 imported baby food products ($F_{test} = 10.53 > F_{critical} = 0.0007$, df = 4). Hence, the type and the CFU of each fungus recovered on DRBC from imported food product are probably dependent on the type of baby food product.

Aflatoxigenic *Aspergillus* species and other fungi from imported baby food products

Aflatoxigenic aspergilli were isolated on AFPA in moderate frequency from 34 % of the samples, accounting for 78.8 % of the total aspergilli and 4.9 % of the CFU (Tab. 4). They were found in the 5 products most heavily contaminating Cerelac, followed by Weetabix, Heinz mixed cereal and the lowest contamination was registered from Cornflakes and Porridge oats (Tab. 2). The finding that Cerelac, a product of wheat and milk, was the most heavily contaminated, is in agreement with the isolation of the aflatoxigenic *A. flavus* in high numbers from baby foods, products of milk powder and cereals (Al-Ashmawy et al. 1993), milk powder (Ismail and Saad 1997), Kishk and biscuits, products of wheat and milk (Ismail 1993, Abdel-Sater and Ismail 1993). Similarly, *A. flavus* was reported regularly from wheat (Moubasher et al. 1972, Mazen et al. 1984, Aran and Eke 1987, Lacey 1988). In other cases however, *A. flavus* was isolated in small numbers from wheat and some of its products (Assawah and Elarosi 1960, Shotwell et al. 1975, Suarez et al. 1981) and it was absent from wheat before harvest (Flannigan 1970). The findings from the current study, whereby *A. flavus* was infrequently isolated from Cornflakes, are not consistent with earlier reports where it was one of the most common species isolated from corn snacks (Zohri et al. 1995), corn (Moubasher et al. 1972, Pitt et al. 1994, Ismail et al. 2003), and corn in the field where the grain suffered insect or hail damage (Bullerman 1979).

On the other hand, the rare incidence of *A. flavus* in Porridge oats is in agreement with the findings of Flannigan (1970), who did not report any *A. flavus* in oats.

Other four *Aspergillus* species in addition to some unidentified *Aspergillus* species were also isolated but infrequently from Cerelac (*A. niger*), Weetabix (*A. niger* and *A. versicolor*), Porridge oats (*A. versicolor*), and Cornflakes (*A. ochraceus* and *A. penicillioides*). In contrast to these findings, *A. niger*, which was infrequent in Cerelac and Weetabix (Wheat products), was found to be one of the most prevalent species in wheat (El-Maghraby 1989). *A. versicolor* was also common in wheat and oats (Flannigan 1970, Moubasher et al. 1972).

Also, 29 other species belonging to 11 genera were encountered on AFPA medium. Cornflakes had the highest number of colony forming units (CFU) of these fungi (15365/g in all samples), followed by Porridge oats (6665), then Cerelac (3725) and Weetabix (1075), whereas Heinz mixed cereal had the least (140). *Fusarium* was recovered in high frequency, contaminating 58 % of the samples from all products, and accounting for 37.3 % of the CFU of all fungi (Tab. 4). Of these products, Porridge oats was the most heavily contaminated with *Fusarium* (possessing 93.7 % of the CFU), followed by Weetabix (60.2 %), Cerelac (18.4 %), Cornflakes (18 %) and Heinz mixed cereal (12.5 %).

Tab. 4. Incidence of aflatoxigenic aspergilli and other fungi on imported baby food products on *Aspergillus flavus/parasiticus* agar (AFPA).

Genera and species	CFU	CFU %	F %	OR	Source
Aflatoxigenic aspergilli	1405	4.90	34	M	1, 2, 3, 4, 5
Other aspergilli	380	1.33	30	M	1, 2, 3, 4, 5
Aspergillus niger	60	0.21	8	R	2, 4
A. ochraceus	75	0.26	2	R	2
A. penicillioides	25	0.09	2	R	2
A. versicolor	10	0.03	4	R	4, 5
Aspergillus spp.	210	0.73	14	L	1, 2, 3, 5
Total *Aspergillus*	1785	6.23	50	H	1, 2, 3, 4, 5
Other fungi	26880	93.77	10	H	1, 2, 3, 4, 5
Chrysosporium farinicola	15	0.05	2	R	5
Cladosporium	2370	8.27	48	M	1, 2, 3, 4, 5
C. cladosporioides	90	0.31	4	R	1, 3
C. herbarum	15	0.05	2	R	3
C. sphaerospermum	2265	7.90	32	M	2, 3, 4, 5
Emericella nidulans	85	0.30	8	R	5
Fusarium	10680	37.3	58	H	1, 2, 3, 4, 5
F. equiseti	45	0.16	6	R	5
F. verticillioides	240	0.84	16	L	1, 2, 3, 5
F. oxysporum	5	0.02	2	R	4
F. poae	1340	4.67	4	R	3
F. proliferatum	550	1.91	2	R	2
F. tricinctum	8130	28.36	28	M	3, 4, 5
Fusarium sp.	370	1.29	18	L	2, 3, 4
Geotrichum candidum	215	0.75	8	R	2, 4
Mucor plumbeus	175	0.61	18	L	2, 4
Neurospora crassa	5	0.02	2	R	1
Paecilomyces variotii	15	0.05	4	R	4
Penicillium	470	1.63	28	M	2, 3, 4, 5
P. citrinum	355	1.24	10	R	2, 4
P. corylophilum	10	0.034	4	R	3, 4
P. islandicum	50	0.17	6	R	3
P. viridicatum	15	0.05	4	R	5
P. waksmanii	25	0.09	4	R	5
Penicillium sp.	15	0.05	4	R	3, 4
Rhizopus oryzae	20	0.07	4	R	1, 5
Total yeasts	12785	44.60	26	M	1, 2, 3, 4, 5
Rhodotorula mucilaginosa	75	0.26	4	R	2, 4
Other yeasts (white)	12710	44.34	26	M	1, 2, 3, 4, 5
Other unidentified fungi	45	0.16	10	R	1, 2, 3, 4
All fungi	28665	100	100	H	1, 2, 3, 4, 5

CFU: colony forming units (number/ g baby food product in 50 samples).
CFU %: Percentage colony forming units (calculated per CFU of all fungi).
% F: Percentage frequency (originated from number of positive samples / 50 tested).
OR: occurrence remarks, High (H) = 50–100 %, Moderate (M) = 25–49 %, Low (L) =13–24 %, Rare (R) = less than 12 %.
Source: 1 = Heinz mixed cereal, 2 = Cerelac, 3 = Cornflakes, 4 = Weetabix, 5 = Porridge oats.

Moderately dominant fungi were *Cladosporium*, *Penicillium* and yeasts. Cerelac was the most heavily contaminated product with *Cladosporium* (representing 40.6 % of the CFU) and *Penicillium* (6.8 %), whereas Cornflakes was most heavily contaminated with yeasts (80.4 %). The remaining fungi were infrequently encountered (Tab. 4).

Incidence of aflatoxins in imported baby foods at the stage of consumption

Nine out of 13 samples analysed during the stage of marketing (69.23 %) were contaminated with aflatoxins. Three levels of contamination were recorded: 0 ppb (4 samples), 1–10 ppb (6), and 11–20 ppb (3). All these are below or in the current tolerance level of 20 ppb accepted in foodstuffs by the Food and Drug Administration (FDA) of the United States of America (Bullerman 1979, Beuchat 1987). All samples of Porridge oats, Cornflakes and Weetabix were contaminated with aflatoxins, while only one of Heinz mixed cereal out of 3 was contaminated (Tab. 5).

Tab. 5. Occurrence of aflatoxigenic aspergilli and total aflatoxins in imported baby foods at the stage of consumption.

Product	Sample No.	Range of total aflatoxins / ppb	% isolates of aflatoxigenic aspergilli
1. Heinz mixed cereal	36	0	28.57
	42	0	0
	46	11–20	42.86
2. Cerelac	45	0	5
	47	0	9
3. Cornflakes	78	11–20	40
	80	1–10	0
4. Weetabix	84	1–10	47.82
	86	1–10	33.3
	85	1–10	33.3
5. Porridge oats	95	11–20	0
	97	1–10	0
	100	1–10	4.34

Cerelac samples tested were aflatoxin-free, although these samples had isolates of aflatoxigenic aspergilli. However, earlier reports on the contamination of wheat with aflatoxins were inconsistent. Cutuli and Fernandez (1984) detected aflatoxins B and G in bread and bakery products, but wheat grown in the North and Midwest of USA was found free of aflatoxins (Shotwell et al. 1975), whereas El-Maghraby (1989) detected aflatoxins B_1, B_2, and G_2 in wheat. The absence of aflatoxins in Cerelac may be attributed to its low moisture content. Abdalla et al. (1973) stated that reduction in fungal activity depended on grain moisture content, whereas Micco et al. (1989) reported that roasting could only destroy a certain percentage of mycotoxins.

Porridge oats, which had the highest moisture content among the products investigated, was the most highly contaminated with aflatoxins at both levels of 1–10 ppb and 11–20 ppb. However, most of its samples (66.7 %) were free from aflatoxigenic aspergilli. This clearly shows that aflatoxins may persist long after vegetative growth has occurred and the aflatoxigenic moulds have died.

Two analysed samples of Cornflakes investigated were contaminated with aflatoxins. Similarly, Zohri et al. (1995) found that many samples of corn snacks, a corn product, were contaminated with aflatoxins. Viquez et al. (1994) stated that corn is a good substrate for aflatoxin production because of its high carbohydrate content and low nitrogen content. Lillehoj et al. (1980) reported high levels of aflatoxin contamination in corn during 1977 in the southern USA and at the Missouri location. Low levels of aflatoxins were found in corn in the northern USA (Shotwell et al. 1975), Egypt (El-Maghraby 1989), Costa Rica (Viquez et al. 1994), and Uganda (Ismail et al. 2003), while aflatoxins were absent from corn grown in the Southern part of the USA (Shotwell et al. 1975).

The three samples of Weetabix investigated were contaminated with aflatoxins at a level of 1–10 ppb. All had aflatoxigenic aspergilli (Tab. 5). On the other hand, Heinz mixed cereal only had one sample out of three contaminated with aflatoxins, which had, together with another one, isolates of aflatoxigenic aspergilli. This implies that the presence of aflatoxigenic moulds in food products does not necessarily mean presence of aflatoxins, although it indicates the potential for mycotoxin contamination and vice versa (Bullerman 1986, Zohri et al. 1995, Ismail et al. 2003).

CONCLUSION

From the current results, Corn flakes and Cerelac (products of corn and wheat, respectively) were the most heavily contaminated by fungi of the five products investigated, while Heinz mixed cereal was the least. *Cladosporium sphaerospermum*, *Fusarium tricinctum* and *Penicillium oxalicum* were the most predominant on DRBC medium. *Aspergillus* (on AFPA) was also predominant on Cerelac having the highest contamination level among the five products. However, aflatoxin analysis revealed that only samples of Cerelac analysed were aflatoxin-free, while samples of the other four products had aflatoxin levels below the current tolerance level of 20_{ppm} accepted in foodstuffs.

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