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Xerophiles and other fungi associated with cereal baby foods locally produced in Uganda

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Fifty samples from five baby food products mainly made of cereal flour(s) were analyzed. The moisture contents of these products were between 11.14% and 11.9%, a level below 14.0%, the recommended level for safe storage of cereal grains and their products. The mycological analysis was carried out using the dilution plate method and two isolation media (DG18 for isolation of xerophilic fungi and DRBC for fungi in general). A total of 80 species related to 37 genera in addition to some unidentified fungal and yeast species were recorded on both media from the five products. The products were contaminated abundantly by xerophilic fungi which were occurring in 88% of food samples and accounting for 18.1% of the total CFU as recorded on DG18. The highest contamination level by xerophiles was registered in Mwebaza rice porridge (a component of rice flour) and the lowest in Mukuza (a product of maize, soyabean and sorghum flours). 11 xerophilic species were recorded of which *Aspergillus* and *Eurotium* (4 species each) were the predominant giving rise to 9.1% and 8.9% of the total CFU, with *A. wentii*, *A. candidus*, *E. cristatum* and *E. repens* were the most contaminating species. Of the fungi recorded other than xerophiles, species of *Aspergillus* (particularly *A. flavus* followed by *A. niger*), *Penicillium* (*P. citrinum*, *P. oxalicum*), *Fusarium* (*F. solani*, *F. tricinctum*), *Cladosporium* (*C. sphaerospermum*) and yeasts were the most predominant. Contamination of such foods is a matter of health hazard as these foods are for babies. So, the use of fresh, well-dried and uncontaminated flours for production of such foods is recommended.

Key words: mycobiota, spoilage, contamination, food products, DG18, DRBC

INTRODUCTION

Baby foods rich in carbohydrates and proteins are being produced from dried cereal and leguminous grains/seeds. The manufacture of baby foods involves mixing the cereal flour with some additional ingredients such as powders of soya beans, dried fish or fruits. Since these dried foods possessed low moisture content levels, they are subject to contamination and spoilage by microorganisms. Fungi 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, Bullerman 1996). Sanchis et al. (1982) noted that certain species if humidity reaches a sufficient level would start producing toxic metabolites. The presence of aflatoxins in foods is of great concern in terms of food safety since they are among the most active ingested carcinogens (Pitt, Hocking 2009). Spoilage of such foods is due to a group of fungi termed as xerophiles that are capable of rapid growth above 0.77 a_w and of slow growth at 0.75 a_w and below-down to about 0.68 a_w. Taligoola et al. (2004); Pitt, Hocking (2009) stated that the most common causes of spoilage of dried cereals are species of *Eurotium* particularly *E. chevalieri, E. repens, E. rubrum* and *E. amstelodami* L. Mangin. A variety of yeasts are also common on cereal grains and flour (Kurtzman et al. 1970; Aran, Eke 1987; Pitt, Hocking 2009). Other ingredients such as powders of soya beans, milk, dried fish and fruits were also found to be contaminated with a wide variety of fungal species (Mislivec, Bruce 1977; Sutic et al. 1979; Bullerman 1979; Jarchovska et al. 1980; Ito, Abu 1985; Pitt et al. 1994; Ismail, Saad 1997; Pitt, Hocking 2009).

Many reports have been published earlier at different localities of the world on the microbiological quality of baby foods (Jarchovská et al. 1980; Moustafa et al. 1984; Abdel-Sater, Ismail 1993; Zohri et al. 1995; Munimbazi, Bullerman 1996) or their ingredients such as wheat (Aran, Eke 1987; Mills et al. 1995), milk powder (Ismail, Saad 1997), rice (Pitt et al. 1994; Taligoola et al. 2004, 2010), maize (Ismail et al. 2003), sorghum (Pitt et al. 1994), millet (Mishra, Daradhiyar 1991), corn chips, breakfast cereal (Bullerman, Tsai 1994; Zohri et al. 1995), and baby foods imported into Uganda (Ismail et al. 2008, 2010).

In Uganda, knowledge about fungi contaminating locally produced foods is needed. Henceforth, this work was designed to survey the xerophilic and other fungi associated with baby foods locally manufactured in Uganda.

MATERIALS AND METHODS

Fifty samples of five baby food products manufactured locally (10 packets each) were randomly collected from different shops at five towns of Uganda (Kampala, Jinja, Mbarara, Masaka and Mbale). Most of these products are made in these towns. Each of these foods contained at least one or more cereal flour. The names, components and the producing companies of these products are shown in Table 1.

Determination of moisture content. Three sub-samples of 50 g each were taken from each food sample and put in aluminium foil dish. These were dried in an oven

Table 1
Food products investigated, their ingredients, producing companies and their mean moisture contents

No	Product	Ingredients	Producing company	Mean moisture content (n=10)
1	Baby soya	Maize flour, soya bean flour, carrot flour	East African Basic Food, Ltd	11.47±0.23
2	Kayebe	Maize flour, powdered Enkejje (*Haplochromis* fish), soya bean flour	Kayebe Sauce Packers, Ltd	11.14±0.38
3	Mwebaza rice porridge	Rice flour	Ebenezer Packers, Ltd	11.9±0.23
4	Jacinta millet flour	Millet flour	Mahimba Company, Ltd	11.6±0.09
5	Mukuza	Maize flour, Sorghum flour, soya bean flour	Hodeco, Ltd	11.52±0.09

at 110°C for 24 hours, and reweighed (Magan, Lacey 1985; Pitt, Hocking 2009). The moisture content of each sample was expressed as the average percentage of the weight loss of the three replicates.

Mycological analysis. All food samples were analyzed mycologically on two isolation media: (1) Dichloran 18% glycerol agar (DG18) which contains glycerol and glucose needed for the growth of xerophilic fungi (Hocking, Pitt 1980) and (2) dichloran rose bengal chloramphenicol agar, DRBC (King et al. 1979). Dilutions were prepared by shaking 10 g of each sample in 90 ml diluent of 0.1% peptone water (Kurtzman et al. 1971). Serial tenfold dilutions were prepared and 1 ml aliquots of the appropriate dilution were placed in sterile Petri dishes. Eight plates were used for each food sample (4 plates for each isolation medium) i.e. 80 plates for each type of food products and in total 400 plates for the fifty food samples. Plates were incubated at room temperature (25-27°C) in day and night cycle of light conditions for 10-14 days for DG18 and for 10 days for DRBC plates. The growing fungi were enumerated, isolated and identified.

Identification of fungi. The identification of different fungal groups was carried out based on their macroscopic and microscopic features using the methods and keys described by Raper, Fennell (1965) for *Aspergillus* and its teleomorphs; Booth (1971) and Leslie, Summerell (2006) for species of *Fusarium*; Pitt (1979) for species of *Penicillium*; Ellis (1971), Moubasher (1993), Domsch et al. (2007), and Pitt & Hocking (2009) for other fungi.

Statistical analysis. Data were subjected to analysis of variance (ANOVA), using the Statistical Analysis System, (SAS institute Inc., 1996). Means were compared with L.S.D. test at $P \leq 0.05$ levels.

RESULTS AND DISCUSSION

Each of the five baby foods investigated contained at least one or more cereal products (Tab. 1).

Moisture content of the products investigated. All samples of the five baby food products were characterized by the average moisture contents ranging from 11.14 %

± 0.38 % in Kayebe to 11.9 ± 0.23 % in Mwebeza rice porridge (Tab. 1). However, all the products had moisture contents below 14.0%, the recommended level for safe storage of cereal grains and their products (Christensen, Kaufman 1974; Taligoola et al. 2004, 2010; Ismail et al. 2003, 2008, 2010).

Incidence of xerophilic fungi in baby food products (recovered mainly on DG18%). Baby foods locally manufactured in Uganda were abundantly contaminated by xerophilic fungi which occurred in 88% of food samples and accounted for 18.08% of the total CFU as recovered on DG18 (Tab. 2). The contamination level with xerophiles ranged from 2.62% of the total CFU in Mukuza to 60.44% in Mwebaza rice porridge (Tab. 3). These high contamination levels with xerophiles indicate that the baby foods may have stayed in shops and supermarkets for a long time where they might have been invaded by storage fungi. Bullerman (1979) reported that, food stuffs in shops and markets are actually under storage, hence fungal contamination is likely to occur. Ten xerophilic species belonging to four genera were recovered from the five products. *Aspergillus* (72% of 50 food samples) and *Eurotium* (64%) were isolated in high incidences while *Wallemia* Johan-Olsen and *Xeromyces* L. R. Fraser were infrequent (Tab. 2). The levels of contamination by xerophilic fungi in locally produced foods (88% of the food samples) were higher than those reported by Ismail et al. (2010) in imported ones (54%), however similar species of the genera *Aspergillus*, *Eurotium* and *Wallemia* were reported from both foods though in different frequencies.

Eurotium (4 species) occurred in 64% of the food samples and constituted the majority of xerophilic CFU (48.89%) from the 5 products. The highest level of contamination with *Eurotium* species was found in Mwebaza rice porridge (24.56% of the total CFU), and the lowest in Mukuza (1.58%) (Tab. 3). *Eurotium* species have been reported on cereal baby foods imported into Uganda (Ismail et al. 2010), maize, rice, soya beans and dried fish (El-Kady, Youssef 1993; Pitt et al. 1994; Taligoola et al. 2004). Among the *Eurotium* species reported, *E. cristatum* and *E. repens* were the most predominant, accounting for 21.17% and 17.98% of the total xerophiles CFU. This finding agrees with earlier reports by Kurata et al. (1968) who found these two species to be common spoilage fungi in many cereals (rice, maize, sorghum, wheat and barley) in storage. The observation of *E. repens* in high occurrence on the foods analysed is inconsistent with the findings whereby *E. repens* and other unidentified *Eurotium* species were recovered in rare frequency on Turkish cereals and cereal products (Aran, Eke 1987). *E. chevalieri* and *E. rubrum* were infrequently encountered, however, these two species were reported earlier as frequent on maize and rice (Kurata et al. 1968; Taligoola et al. 2004) and on baby foods imported to Uganda (Ismail et al. 2010).

Xerophilic aspergilli (4 species) accounted for 50.13% of the xerophiles CFU and 9.06% of the total fungi CFU (Tab. 2). They were recovered in 72% of food samples from the five products. The highest level of contamination was found in Mwebaza rice porridge (35.87% of the total CFU) and the lowest was registered in Mukuza (1.04%). *A. wentii* was the most prevalent species, accounting for 25.95% of the xerophiles CFU. It was found most heavily contaminating Kayebe and Baby soya (major components: maize and soyabeans). In this respect, low levels of infection by *A. wentii* were recorded on soya beans, maize, paddy rice and sorghum in Thailand and Indonesia (Pitt et al. 1994) and on maize (Ismail et al. 2003) and rice (Taligoola

Table 2
Incidence of fungi in local baby food products on dichloran 18% glycerol agar (DG18) and dichloran rose Bengal chloramphenicol agar (DRBC)

Taxa	DG18					DRBC				
	CFU	CFU%	F%	OR	Source	CFU	CFU%	F%	OR	Source
Xerophilic fungi	28225	18.08	88	H	1,2,3,4,5	1825	1.08	25	M	1,2,3,5
Aspergillus (Total)	14150	9.06	72	H	1,2,3,4,5	1250	0.74	20	L	
A. candidus Link	6550	4.20	16	L	1	150	0.09	6	R	5
A. penicillioides Spegazzini	175	0.11	8	R	1,3,5	50	0.03	4	R	1,2
restrictus Smith	100	0.06	8	R	1,2,3	75	0.04	4	R	1,2
A. wentii Wehmer	7325	4.71	72	H	1,2,3,4,5	975	0.58	14	L	2
Eurotium (Total)	13800	8.87	64	H	1,2,3,4,5	500	0.30	10	R	1,2,3
E. chevalieri Mangin	2475	1.59	18	L	2,3,4,5	200	0.10	6	R	3
E. cristatum (Raper & Fennell) Malloch & Cain	5975	3.84	56	H	1,2,3,4,5	300	0.20	4	R	1,2
E. repens de Bary	5075	3.26	34	M	1,2,3,4,5					
E. rubrum Konig, Spieckermann & Bremer	275	0.18	8	R	1,3					
Polypaecilum pisce A. D. Hocking & Pitt						25	0.014	2	R	1
Wallemia sebi (Fries) von Arx	150	0.09	4	R	1	50	0.03	2	R	1
Xeromyces bisporus L. R. Fraser	125	0.08	2	R	1					
Xerotolerant fungi	127900	81.92	100	H	1,2,3,4,5	167415	98.92	100	H	1,2,3,4,5
Acremonium strictum W. Gams	25	0.02	2	R	5	200	0.12	10	R	1,3
Acrophialophora sp.						7525	4.4	4	R	3
Alternaria alternate (Fries) Keissler						75	0.04	2	R	2
Aspergillus (Total)	32700	20.95	82	H	1,2,3,4,5	39010	23.05	84	H	1,2,3,4,5
A. aegyptiacus Moubasher & Moustafa						50	0.03	2	R	1
A. carbonarius (Bainier) Thom	125	0.08	2	R	1	75	0.04	2	R	1
A. deflectus Fennell & Raper						25	0.014	2	R	1
A. flavus Link	23725	15.19	64	H	1,2,3,4,5	30435	18.0	74	H	1,2,3,4,5
A. fumigates Fresenius	1000	0.64	20	L	1	975	0.5	16	L	2,3
A. niger van Tieghem	1575	1.01	42	M	1,2,3,4,5	1800	1.1	32	M	1,2,3,4,5
A. nomius Kurtzman, Horn & Hesseltine	25	0.02	2	R	1					
A. ochraceus Wilhelm	800	0.51	30	M	1,2.3,4	450	0.3	12	R	2,3,5
A. oryzae (Ahlburg) Cohn	1800	1.15	22	L	2,3,4	525	0.3	14	L	L,2,3
A. parasiticus Speare	50	0.03	4	R	2	225	0.13	10	R	1,2
A. phoenicis (Corda) Thom						25	0.014	2	R	3
A. sydowii (Bainier & Sartory) Thom & Church	725	0.46	12	R	1,3,5	375	0.2	8	R	2,3
A. tamari Kita	2075	1.33	22	L	2,3,4	3050	1.8	24	L	1,2,3
A. terreus Thom	125	0.08	6	R	1,3	550	0.3	8	R	2,3
A. versicolor (Vuillemin) Tiraboschi	675	0.43	22	L	1,2,3,5	450	0.3	18	L	1,3

Table 2 – cont.

Botryotrichum piluliferum Saccardo & Marchal						50	0.03	2	R	1
Byssochlamys fulva S. L. Ollivr & G. M. Smith	525	0.34	6	R	3					
Chaetomium sp.						25	0.014	2	R	1,5
Cladosporium (Total)	6175	3.95	68	H	1,2,3,4,5	2655	1.6	46	M	1,2,3,5
C. cladosporioides (Fresenius) de Vries	3700	2.37	34	M	1,2,3,5	425	0.14	8	R	1,3,5
C. herbarum (Persoon) Link	25	0.02	2	R	1					
C. sphaerospermum Penzig	2450	1.57	40	M	1,3,4,5	2230	1.3	40	M	1,2,3,4,5
Cochliobolus lunatus R. Nelson & Haasis						50	0.03	4	R	1
Curvularia sp.						25	0.014	2	R	3
Doratomyces sp.						25	0.014	2	R	3
Emericella nidulans (Eidam) Vuillemin						150	0.09	2	R	3
Epicoccum nigrum Link						25	0.014	2	R	1
Eupenicillium sp.						150	0.09	8	R	2,5
Fennellia flavipes Wiley & Simmons						25	0.014	2	R	1
Fusariella sp.						50	0.03	2	R	1
Fusarium (Total)	13550	8.68	42	M	1,2,3,4,5	43300	25.6	56	H	1,2,3,4,5
F. equiseti (Corda) Saccardo						50	0.03	4	R	4
F. lateritium Nees	3125	2.0	16	L	4					
F. oxysporum Schlechtendal	25	0.02	2	R	1					
F. poae (Peck) Wollenw.	25	0.02	2	R	3					
F. solani (Martius) Saccardo	25	0.02	2	R	4	24100	14.25	26	M	1,2,3,4,5
F. tricinctum (Corda) Saccardo	9850	6.31	12	R	5	17775	10.5	20	L	1,5
F. verticillioides (Saccardo) Nirenberg	425	0.02	10	R	2,3	1375	0.8	32	M	1,3,4,5
Fusarium sp.	75	0.05	2	R	3					
Geotrichum candidum Link						25	0.014	2	R	5
Hypomyces chrysospermus Tul.						75	0.04	4	R	1
Lasiodiplodia theobromae (Pat.) Griffon & Maubl.						50	0.03	2	R	1
Microdochium nivale (Fries) Samuels & Hallett	150	0.09	6	R	5	125	0.07	6	R	1,3
Monilia sp.						200	0.1	2	R	1
Mucor (Total)						4275	2.5	20	L	1,2,3,5
M. plumbeus Bonord.						1950	1.2	12	R	1,2,3,5
M. racemosus Fresenius	200	0.13	8	R	1,3	150	0.09	6	R	2,3
Mucor sp.						2175	1.3	14	L	2,3
Neosrtorya fischerii (Wehmer) Malloch & Cain	100	0.06	2	R	3	4325	2.6	2	R	3
Neurospora crassa (Shear & Dodge) v. Arx	23475	15.04	30	M	3,4,5	8175	4.8	28	M	2,3,4,5
Paecilomyces variotii Bainier	400	0.26	10	R	1,3	350	0.2	12	L	1,2,3

Penicillium (Total)	16625	10.65	80	H	1,2,3,4,5	13400	7.9	58	H	1,2,3,4,5
P. chermesinum Biourge	150	0.09	6	R	5					
P. chrysogenum Thom	650	0.42	8	R	2					
P. citrinum Thom	4025	2.58	28	M	1,2,3,5	5950	3.5	40	M	1,2,3,4,5
P. corylophilum Dierckx	7525	4.82	18	L	2,3,4,5	250	0.15	8	R	1,2,3
P. islandicum Sopp	50	0.03	2	R	3					
P. oxalicum Currie & Thom	4125	2.64	44	M	1,2,3,4,5	6075	3.50	24	L	2,3,4
P. pinophilum Hedgcock						75	0.04	6	R	3
P. puberulum Bainier						25	0.014	2	R	3
P. purpurogenum Stoll	50	0.03	2	R	1					
P. variabile Sopp						75	0.04	4	R	1,3
P. viridicatum Westling						950	0.5	16	L	1,2
Penicillium sp.	50	0.03	2	R	3					
Phoma sp.						325	0.2	2	R	1
Rhizopus stolonifer (Ehrenberg) Vuillemin	4100	2.63	22	L	3,4,5	5075	3.0	36	M	1,3,4,5
Scopulariopsis candida (Gueguen) Vuillemin						50	0.03	2	R	1
Thermoascus aurantiacus Miehe						25	0.014	2	R	2
Trichoderma harzianum Rifai						50	0.03	4	R	1,2
Other unidentified fungi						1250	0.74	18	L	1,3,5
Yeasts	29375	18.81	22	L	1,2,3	35775	21.2	34	M	1,2,3,4,5
Rhodotorula mucilaginosa (Jörgensen) Harrison	250	0.16	2	R	2	975	0.6	20	L	2,3
Yeasts (brown)						125	0.07	4	R	1,4
Yeasts (white)	29125	18.65	22	L	1,2,3,5	34750	20.5	14	L	3,4,5
Yeasts (yellow)						25	0.014	2	R	3
Total fungi	156125	100	100	H	1,2,3,4,5	169240	100	100	H	1,2,3,4,5
No. of genera (37)			16					36		
No. of species (80)			48					65		

Abbreviations: CFU = Colony forming units (calculated /g baby food product in 50 samples); CFU% = Percentage colony forming units (calculated per total fungal CFU); F% = percentage frequency (calculated per 50 samples investigated); OR = occurrence remarks; High (H) = 50-100 %, Moderate (M) = 25-49 %, Low (L) = 13-24 %, Rare (R) = less than 13 %; Source: 1 = Baby soya, 2 = Kayebe, 3 = Mwebaza rice porridge, 4 = Jacinta millet flour, 5 = Mukuza.

Table 3
Colony forming units and percentage frequency of most common fungi, and the number of genera and species recovered from the five baby food products on DG18 and DRBC

Product	Baby soya				Kayebe				Mwebaza rice porridge				Jacinta millet flour				Mukuza.			
Medium	DG18		DRBC		DG18		DRBC		DG18		DRBC		DG18		DRBC		DG18		DRBC	
Common fungi	CFU	F%	CFU	F%	CFU	F%	CFU	F%	CFU	F%	CFU	F%	CFU	F%	CFU	F%	CFU	F%	CFU	F%
Xerophiles	1500	70	375	50	9275	100	1125	50	11200	100	200	30	5175	90			1075	80	100	20
Eurotium cristatum	375	70	25	10	2925	60	275	10	2150	50			300	40			225	60		
E. repens	375	70			1200	30			275	40			3100	20			125	20		
Aspergillus wentii	325	60	150	30	5025	100	825	40	150	40			1525	80			300	80		
Xerotolerants	2900	100	4505	100	35200	100	47910	100	7325	100	21400	100	42000	100	47275	100	39975	100	46350	100
A. flavus	275	50	400	60	21075	100	26660	100	400	70	1750	70	1125	40	575	70	850	60	1050	70
A. niger	125	20	225	40	525	70	700	60	175	30	800	30	625	60	25	10	125	30	50	20
A. ochraceus	100	30			250	50	75	20	375	50	350	30	75	20					25	10
Cladosporium cladosporioides	625	40	50	10	2750	60			250	60	350	20					75	10	25	10
C. sphaerospermum	275	30	805	80			75	40	600	40	500	30	1100	60	550	10	475	70	300	40
Fusarium solani			100	20									25	10	23925	100			75	10
F. verticillioides			325	30	125	10	200	10	300	40	350	60			275	20			225	40
Neurospora crassa							75	10	300	30	100	20	23050	100	7825	100	125	20	175	10
Penicillium citrinum	100	20	250	40	2850	50	4125	80	575	30	1250	30			175	40	500	40	150	10
P. oxalicum	75	20			475	50	5875	90	900	30	150	10	2625	100	50	20	50	20		
Rhizopus stolonifer			25	10					325	40	300	40	3725	50	4550	90	50	20	150	40
Yeasts (Total)	75	10	25	10			600	50			350	50	125	10	725	20			34075	40
CFUs of all fungi	4400	100	4880	100	44475	100	49035	100	18525	100	21600	100	47175	100	47275	100	41050	100	46450	100
No. of genera	8		24		4		11		12		18		7		6		7		8	
No. of species	25		39		19		27		35		34		16		10		20		16	

For abbreviation see Table 2; A= Product, B= Medium, C= Common fungi; A*B*C L.S.D at $P \leq 0.05 = 210.52$

et al. 2004) in Uganda. *A. candidus* was the second most common xerophilic *Aspergillus* species. It was recovered in 16% of the samples, however giving rise to high percentages of CFU (23.21% of xerophiles) and found only in Baby soya. *A. penicillioides* and *A. restrictus* occurred infrequently in Baby soya, Kayebe, Mwebaza rice porridge or Mukuza. These two species were also uncommon in maize and rice in Uganda (Ismail et al. 2003; Taligoola et al. 2004), and in baby foods imported to Uganda (Ismail et al. 2010), while *A. restrictus* was predominant on cereal grains in Iran (Lacey 1988) and *A. penicillioides* was isolated in high frequency from soya beans in Thailand (Pitt et al. 1994) and dried fish in Indonesia (Wheeler et al. 1986). The presence of *A. restrictus* on Baby soya and Kayebe (products of soya beans), is in agreement with the finding where *A. restrictus* was found invading soya beans whose moisture contents were between 12.5%-13% (Christensen, Kaufmann 1965). This fungus was first reported in stored grains by Tuite, Christensen (1955) and since then has been found to be a common cause of deterioration in all kinds of stored grains and seeds (Christensen, Kaufmann 1965).

Wallemia sebi and *Xeromyces bisporus* were infrequently encountered and only from Baby soya. *W. sebi* was earlier reported in maize and soya beans from Thailand, and on peanuts, maize, paddy and milled rice, and soya beans from Indonesia (Pitt et al. 1994) and on Pakistani and Ugandan rice (Taligoola et al. 2004), while *X. bisporus* was reported from dried prunes, spice powders, nutmegs, dates, fruit cakes and cookies (Pitt, Hocking 2009).

It is worthy to mention that 7 of these xerophilic species in addition to *Polypaecilum pisce* were reported on DRBC but infrequently, accounting for a minor proportion of total CFU (1.08%).

Incidence of fungi other than xerophiles in baby food products (recovered on both DG18 and DRBC). Apart from the 11 xerophilic species, baby food products yielded a total of 33 genera and 69 species of xerotolerant fungi on both DG18 (38 species and 12 genera) and dichloran rose Bengal chloramphenicol agar (DRBC) (57 species belonging to 32 genera). The broadest spectrum of species was recorded in Mwebaza rice porridge (35 species on DG18) and in Baby soya (39 species on DRBC), while the narrowest was recorded in Jacinta millet flour (16 species on DG18 and 10 species on DRBC). The current results revealed that the diversity of fungi was higher in locally produced foods (36 genera and 65 species on DRBC) than in imported ones (21 and 42) analysed by Ismail et al. (2008). *Aspergillus*, *Penicillium*, *Fusarium* and *Cladosporium* were the most predominant genera on both isolation media (Tab. 2). *Penicillium* and *Aspergillus* were reported earlier as the most commonly isolated genera on starches (potatoes, rice, maize and wheat) intended for human consumption (Suarez et al. 1981), on wheat, maize, sorghum and barley in Egypt (Moubasher et al. 1972; El-Maghraby 1989). In a study on baby foods imported into Uganda, the most common fungal genera were found to be similar to those reported in the current study from the local foods, however, species of *Aspergillus* and *Penicillium* were more dominant in locally produced foods, while species of *Cladosporium* and *Fusarium* were more common in imported ones (Ismail et al. 2008).

Aspergillus was the most frequent genus. It emerged from 82% and 84% of food samples accounting for 20.95% and 23.05% of the total CFU on DG18 and DRBC respectively. It was represented by 15 species of which *A. flavus* was the most common. *A. flavus* accouned for 15.19% and 18.0% of the total fungi CFU on DG18 and

DRBC, respectively (Tab. 2). It was recovered in high frequency from all products on both media but had its highest level of contamination in Kayebe (Tab. 3). The high incidence of *A. flavus* on Kayebe whose major components are maize, soya beans and fish flours, is in agreement with earlier reports on maize (El-Maghraby 1989; Sebunya, Yourtee 1990, Munimbazi, Bullerman 1996, Ismail et al. 2003), on dried fish (Ito, Abu 1985) and on soya beans (El-Kady, Youssef 1993). Contrary to the above findings, *A. flavus* was reported with low occurrence in maize and sorghum in Egypt (El-Kady et al. 1982) and soya beans in Uganda (Sebunya, Yourtee 1990).

A. niger came second and was found contaminating 42% and 32% of food samples from the five products, accounting for 1.01% and 1.1% of the total fungi CFU on DG18 and DRBC, respectively. It was recovered in moderate frequency and most heavily contaminating Kayebe and Baby soya (products of maize and soya beans). This is in agreement with the findings of Suarez et al. (1981), who recovered *A. niger* from starches intended for human consumption, where rice and maize were among these starches. Also, Sanchis et al. (1982) fond that *A. niger* caused severe deterioration to corn and sorghum. Other four *Aspergillus* species were recovered in low frequency of occurrence on both media, accounting collectively for 3.55% and 4.75% of the total fungi CFU on DG18 and DRBC media, respectively, and these were: *A. fumigatus*, *A. oryzae*, *A. tamarii* and *A. versicolor* (Tab. 2). Earlier reports mentioned these species to occur less commonly on freshly ground mouldy maize meal (Marasas, Smalley 1972). *A. ochraceus* was reported moderately on DG18 but rarely on DRBC giving rise to 0.51% and 0.3% of the total CFU respectively. On the other hand, 8 species of *Aspergillus* were isolated in rare incidence on one or both media: *A. aegyptiacus*, *A. carbonarius*, *A. deflectus*, *A. nomius, A. parasiticus*, *A. phoenicis*, *A. sydowii* and *A. terreus* (Tab. 2). *A. carbonarius* and *A. parasiticus* have been reported as rare species in food products imported into Uganda (Ismail et al. 2008, 2010), though some of the above species have been reported to be common on barley e.g., *A. sydowii*, *A. ochraceus*, *A. terreus* (Moubasher et al. 1972) and *A. terreus* on maize (Ismail et al. 2003), paddy rice (Abdel-Hafez et al. 1987) and flour (Augustine et al. 1984).

Penicillium was the second most frequent genus, recovered from 80% and 58% of the total food samples on DG18 and DRBC respectively, accounting for 10.65% and 7.9% of the total CFU. The highest levels of contamination with penicillia were recorded in maize flour-containing products (Kayebe and Baby soya), and Mwebaza rice porridge and the least was found in Mukuza (Tabs 2 and 3). The above findings agree with earlier observation where *Penicillium* was among the most common genera recovered from corn snacks (Zohri et al. 1995) and starches (Suarez et al. 1981). Similarly, corn was found to be highly contaminated with *Penicillium* species, while rice was found to be penicillia free (Munimbazi, Bullerman 1996). In contrast to our finding, whereby Mukuza (a product of sorghum) had a low contamination level with *Penicillium* species, Diener et al. (1981) found *Penicillium* to be among the most dominant genera on sorghum. *P. citrinum* (2.58% and 3.5%) and *P. oxalicum* (2.64% and 3.5% of the total CFU on DG18 and DRBC respectively), the most common species in the present study, have been reported earlier to occur on starches (Suarez et al. 1981), and barley (Abdel-Kader et al. 1979). *P. oxalicum* was also one of the chief species isolated from unstored corn kernels (Mislivic, Tuite 1970) and in preharvest corn from Valencia, Spain (Jimenez et al. 1985). *P. citrinum*, a nephrotoxigenic fungus, is known as citrinin-producer (Mislivec, Tuite 1970; Frisvad 1983). *P. viridicatum*, a well known nephrotoxigenic species (Frisvad 1983) and *P. corylophilum* were also isolated though in low frequency, respectively on DRBC and DG18, constituting 0.5% and 4.82% of the total CFU. *P. viridicatum* was earlier recovered from starches intended for human consumption (Suarez et al. 1981). Carlton et al. (1968) found that *P. viridicatum*, *P. oxalicum* and *P. multicolor* Grig.-Manoil. & Porad, all isolated from corn kernels in Indiana were toxic to mice when included in their diets. Other 7 *Penicillium* species: *P. chermesinum, P. chrysogenum, P. islandicum, P. pinophilum*, *P. puberulum*, *P. purpurogenum* and *P. variabile* were rarely isolated from only one or two products (Tab. 2). Of these, *P. variabile* has been reported to cause severe deterioration in wheat, corn and sorghum (Moubasher et al. 1972) and *P. aurantiogriseum, P. chrysogenum, P. corylophilum*, *P. citrinum, P. expansum*, *P. islandicum*, *P. oxalicum*, *P. verrucosum*, *P. viridicatum* from baby foods imported into Uganda (Ismail et al. 2008, 2010).

Fusarium occupied the third place with regard to its frequency, occurring in 42% and 56% of the samples on DG18 and DRBC respectively. However its count (25.6% of the total CFU) was more than that of *Aspergillus* and *Penicillium* on DRBC while lower than that of both genera on DG18 (Tab. 2).This result agrees with the earlier finding that species of *Fusarium* are field fungi (Moubasher et al. 1972; Christensen 1987) less tolerating the low water activity medium, DG18. The results revealed that *Fusarium* represented the highest and the major food-contaminant. Among the five products investigated, Jacinta millet flour and Mukuza were the most heavily contaminated having *Fusarium* CFU in all their samples. It is possible that fusaria infected the cereals while still in the field and persisted even after the cereals were processed and stored. Of eight species encountered, *F. solani* (0.02% and 14.24% of the total CFU) and *F. tricinctum* (6.31% and 10.5%) were the most contaminating on both DG18 and DRBC respectively, though these were recovered in rare to moderate frequency. *F. solani* was found most heavily contaminating Jacinta millet flour while *F. tricinctum* in Mukuza (a product of sorghum and maize). This finding disagreed with earlier reports where *F. solani* and *F. tricinctum* were absent on millet and sorghum (Diener et al. 1981; Munimbazi, Bullerman 1996). *F. verticillioides* constituted low percentages of the total CFU and was found most heavily contaminating Baby soya and Mwebaza rice porridge (products of maize and rice flour, respectively). *F. verticillioides* and *F. tricinctum* were registered earlier in maize meal (Marasas, Smalley 1972), maize stalks and grains (Logrieco et al. 1988), and sorghum (Diener et al. 1981). *F. verticillioides* is a major producer of moniliformin and fumonisins toxins that cause liver cancer in rats and oesophageal cancer in humans (Lacey 1988, Logrieco et al. 1988; Sydenham et al. 1990). The remaining *Fusarium* species were recorded infrequently either on DG18 (*F. lateritium* from 8 food samples from Jacineta millet flour, *F. oxysporum* from one Baby soya sample, *F. poae* from one sample of Mukuza and unidentified *Fusarium* species from one sample of Mwebaza) or on DRBC (*F. equiseti* from only 2 samples of Baby soya).

Cladosporium (3 species) was also isolated from all products in high frequency (68% of food samples) on DG18 and moderate frequency (46%) on DRBC, constituting 3.95% and 1.6% of the total CFU on DG18 and DRBC, respectively. *C. sphaerospermum* was moderately isolated on both media with 1.57% and 1.3% of the total CFU while *C. cladosporioides* was moderate on DG18 and rare on DRBC

(Tab. 2). *C. herbarum* was rare and recovered only from 1 sample of Kayebe. In this respect, Mazen et al. (1984) found *C. sphaerospermum* in low frequency on maize.

Neurospora crassa, *Rhizopus stolonifer* and yeasts (with *Rhodotorula mucilaginosa* being the most common) were all isolated in moderate or low frequency on DG18 and in moderate frequency on DRBC. These species were reported earlier as food spoilage fungi (Pitt, Hocking 2009). *R. stolonifer* had also been reported earlier from soya beans (El-Kady, Youssef 1993) and barley (Abdel-Kader et al. 1979).

Some other fungal species were isolated infrequently either in low or rare frequency from one or more food products on DG18 or DRBC or both (Tab. 2).

Analysis of variance. Analysis of variance was computed on baby food products using Anova test at 5% significance level (Tab. 3). The calculated value of $F_{test} = 8.84$ at df 4. This is greater than the tabulated value $F_{critical} = 1.96316$, hence there is a significant difference in the total count of the different species recovered from the different food products on DRBC and DG18. The type and the CFU of most fungal species recovered on DRBC and DG18 from food products are probably dependent on the type of that product. This may also be due to the different ingredients including cereal flours involved in these products.

CONCLUSIONS

The current results revealed that Kayebe (a product of maize, fish and soya bean) and Jacinta millet flour (a product of millet) were the most heavily contaminated by fungi CFU of the five products investigated, while Baby soya was the lowest as determined on both isolation media. However, the highest contamination level by xerophiles was registered in Mwebaza rice porridge and the lowest in Mukuza. Among eleven xerophilic species recorded on these baby foods, species of *Aspergillus* and *Eurotium* were the most common. In addition, a high incidence of *Aspergillus flavus,* Yeasts, *Fusarium solani, F. tricinctum, Penicillium citrinum, P. corylophilum, P. oxalicum* and *Cladosporium sphaerospermum* on one or both isolation media were also recorded. Many of these fungi are capable of producing mycotoxins. Contamination of such foods (especially those for babies) is a matter of health hazard for human consumption. However their safety can be insured and improved greatly by using quality raw materials. As contamination occurs for cereal grains before, during or after harvesting, during drying process, or even during food production and this contamination could also be due to long-term storage, marketing under non-hygienic conditions of the food products. We suggest that monitoring fungal contaminations as well as mycotoxins should be carried out periodically and procedures to prevent mould contamination should be developed.

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