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IMPACT OF SEASONAL CHANGES ON THE DISTRIBUTION AND PATHOGENICITY OF *Aspergillus flavus* ON DRIED FERMENTED COCOA BEANS IN SOUTHWESTERN NIGERIA

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SUMMARY

This study aimed to determine the distribution and pathogenicity of fungi populations associated with stored cocoa beans in dry and wet environmental conditions within southwestern Nigeria. Dried fermented cocoa beans were collected from randomly selected cocoa stores in Ibadan, Ijebu Igbo, Ile Ife, Akure and Ado Ekiti in Oyo, Ogun, Osun, Ondo and Ekiti States, respectively during dry and wet seasons. Fungi associated with the beans samples were isolated, identified and pathogenicity of the most occurring species was determined. *Aspergillus flavus* (4.76-88.24%), *A. niger* (7.69-100.00%) and *Rhizopus* spp. (7.14-81.81%) were mostly isolated from the cocoa beans samples stored under the two storage conditions. Six out of the thirteen moulds isolated from the collected beans samples from across the states, were *Aspergillus* species. Other isolated moulds include *Fusarium* spp. (7.69 – 100.00%), *Rhizopus* spp. (8.33 – 81.81%), *Neurospora* spp. (6.25 - 22.22%), *Pythium* spp. (18.18 – 58.33%) and *Trichoderma* spp. (50.00%), *Penicillium* sp. (8.33 – 15.38%) and *Lasiodiplodia theobromae* (9.09 – 81.81%). Also, only two out of the 46 *A. flavus* dry-season isolates showed high pathogenicity, while one isolate did not show visible symptom of seed infection. Similar trend was observed on the remaining fifty-four (54) wet season *Aspergillus* isolates. *Aspergillus* spp. and *Rhizopus* spp. were mostly associated with dried fermented cocoa beans at storage in Southwest Nigeria. Most strains of *A. flavus* were however able to cause varying degrees of infections on stored cocoa beans both during dry and wet seasons of the year. Further work however need to be done, to find lasting solutions to the problem of fungal and mycotoxin contamination of dried fermented cocoa beans at storage.

Keywords: Fungi, populations, storage, infection, cocoa

Cocoa beans are an important commodity for foreign earnings in producing countries. Although Nigeria is known to be one of the major cocoa producers in the world, production levels of the crop in the country ranged between 280, 000 – 290,000 metric tonnes annually, between year 2020 and 2023, thus plunging the country at the fifth position on the global table (19).

A variety of fungi including the ochratoxin producers: *Aspergillus carbonarius*, *A. niger* , *A. ochraceus*, *A. melleus* and *A. westerdijkiae,* as well as the aflatoxins producers *A. flavus*, *A. nomius* and *A. parasiticus* in addition to *Absidia corymbifera*, *Aspergillus* sp. nov. (related to *A. tamarii*), *P. paneum*, *A. candidus*, and *Eurotium chevalieri* have also been found

in sun-dried cocoa beans (7).

The extent to which mouldiness occur in stored cocoa beans by fungi is inestimable. The bean cotyledons are grossly affected, resulting into colour change from cream to green, yellow, black, brown or white in the cocoa beans (9). The presence of mould (s) in a bean can be readily seen with the naked eye, especially when they are advanced in growth (9).

Besides the physical alterations noticed on infected stored cocoa beans, some secondary metabolites of importance are also being produced by some associated toxigenic moulds, mostly of the *Aspergillus, Penicillium* and *Fusarium* genera. These metabolites are known as toxins or mycotoxins . Mycotoxins are toxic compounds that are naturally produced by certain types of moulds. Most mycotoxins are chemically stable and survive food processing (20). The mechanism of operation of the storage moulds associated with dried fermented cocoa beans however need to be well understood for effective prevention and control.

This study therefore aimed at determining the population diversity and pathogenicity of fungi associated with stored cocoa beans in dry and wet seasons from Southwestern Nigeria.

METHODOLOGY

Isolation and characterization of fungi associated with stored cocoa beans

Representative samples of infected dried cocoa beans (100-250 beans) which had been stored for three months were obtained twice from twenty randomly selected cocoa stores across the major cocoa producing States: Ondo (Akure), Osun (Ile Ife), Oyo (Ibadan), Ekiti (Ado Ekiti) and Ogun (Ijebu Igbo) in Southwest Nigeria, using multistage sampling procedure which included purposive and simple random sampling techniques (3). Forty different samples were obtained both in the dry season and rainy season of the year (2020). The cocoa beans samples obtained were kept in sealed sterile Ziploc bags and transported within 24 hours of collection to the Mycology Laboratory in Cocoa Research Institute of Nigeria, Ibadan for further analysis.

The infected cocoa beans obtained from each of the cocoa store locations were cut into small pieces with the aid of a sterile knife and surface-sterilized in 2% sodium hypochlorite for two minutes. The beans were then rinsed thrice with sterile distilled water. The surface-sterilized samples were blotted-dried with the aid of sterile serviette papers and inoculated into freshly prepared Potato Dextrose Agar (PDA) in Petri dishes (17;15). The plates were incubated at 30±2^{o} C for 5 days. Isolated filamentous fungi (moulds) were purified and identified using Watanabe (2002) fungi atlas.

Pathogenicity Testing

Dried fermented healthy cocoa beans of F3 Amazon variety were obtained from Cocoa Research Institute of Nigeria (CRIN) headquarters, Ibadan. The beans were moist-sterilized at 121^{o}C for 15 minutes and kept in cool dry place within well sealed sterile conical flasks until further use. Nine millimeter (9.0 mm) of 5day old culture disc of each of the most occurring storage moulds were suspended in 10 ml sterile distilled water. The spores were filtered and suspended in sterile distilled water, in serial concentrations to make a spore suspension of 1.0 x 10^{6} spore/ml with the aid of a haemocytometer. Three freshly sterilized cocoa beans were then immersed into each of the fungal spore suspensions for 18 hours.

Freshly sterilized and cooled (45^{o} C) water agar was dispensed into sterile Petri dishes and allowed to gel. The immersed cocoa

beans samples were brought out, drained and transferred into the water agar plates in triplicates, and incubated at 30±2° C for 7 days (Hussain *et al.*, 2013). The pathogenicity of infection of cocoa beans samples by each of the fungal strains was observed and rated using the following scale (13): 1 (less than 1% seed area infected), 2 (1-10% seed area infected), 3 (11-25% seed area infected), 4 (26-50% seed area infected), 5 (More than 50% seed area infected).

RESULTS

The percentages of occurrence of moulds isolated from dried fermented cocoa beans stored during the dry season (between December and February, 2019/2020) across cocoa producing States of Southwest Nigeria are presented in Table 1. A total of twelve species of the storage moulds were isolated from the beans. Six of them were species of *Aspergillus*. Out of these twelve moulds, *Aspergillus flavus, A. niger, Rhizopus* spp., *A. ochraceous* and *A. parasiticus* were most predominant. *Aspergillus flavus* (4.76 - 77.78%) and *A. niger* (7.69 - 100%) were each isolated from fourteen out of the twenty samples collected. *Rhizopus* spp. (14.29 - 33.33%), *A. ochraceous* (3.85 - 20.00%) and *A. parasiticus* (11.11 - 52.38%) were isolated from eleven, seven and six samples respectively. *Neurospora* spp. (20.00%), *Pythium* spp. (25.00%) and *Trichoderma* spp. (50.00%) were only isolated from Ado Ekiti Store 3, Ijebu Igbo Store 4 and Ibadan Store 1 samples, respectively.

The percentages of occurrence of moulds isolated from dried fermented cocoa beans stored during the wet season of the year from selected cities across cocoa producing States of Southwest Nigeria are as shown in Table 2. *Aspergillus flavus* (8.33 - 88.24%) was isolated from fifteen out of the twenty samples obtained, followed by *Rhizopus* spp. (7.14 - 50.00%) which was isolated from thirteen out of the twenty samples.

Unlike other moulds' occurrence observed on the dry season samples, *Lasiodiplodia theobromae* (8.34 - 77.78%) was more frequently isolated from the wet season samples. It was isolated from eight out of the twenty samples. *Fusarium* spp. (11.76 - 50.00%) and *A. niger* (8.33 - 40.00%) were each isolated from six samples, while *A. fumigatus* (18.18) was only isolated from one of the samples (Table 2). *Aspergillus flavus* was isolated from all the cocoa beans samples obtained from randomly selected cocoa stores in Ijebu Igbo (Ogun State) and Ibadan (Oyo State), but only from one of the samples from Akure (Ondo State) cocoa stores. *Neurospora* spp. were isolated from four of the wet season samples contrary to what was observed on the dry season samples. Similar trend was also observed on *Pythium* spp. *Penicillium* spp. isolated from two wet season samples were not isolated from any of the dry season samples. Also, *Trichoderma* spp. were not isolated from the wet season samples, but isolated from the dry season samples.

A total of thirteen species of moulds were isolated from both dry and wet season samples, out of which eleven were of the same (*Aspergillus*) genus (Figures 1a-d). *Trichoderma* spp. isolated from only one of the dry season samples were not isolated from any of the wet season samples. In the same vein, *Penicillium* spp. recovered only two of the wet season samples were not present on any of the dry season samples (Tables 1 and 2).

Table 1: Percentage occurrence of fungi associated with stored cocoa beans obtained in dry season across South-West, Nigeria

Location (Cocoa store)	Storage fungi											
	Aspegillus flavus	*A. parasiticus*	*A. nidulans*	*A. niger*	*A. ochraceous*	*A. fumigatus*	*Fusarium* spp.	*Pythium* spp.	*L. theobromae*	*Rhizopus* spp.	*Neurospora* spp.	*Trichoderma* spp.
Ile Ife 1	4.76	52.38	-	-	9.52	-	-	-	-	33.33	-	-
Ile Ife 2	76.92	-	-	7.69	7.69	-	7.69	-	-	-	-	-
Ile Ife 3	45.45	27.27	-	-	9.09	-	-	-	-	18.18	-	-
Ile Ife 4	-	-	56.25	18.75	-	-	-	-	-	25.00	-	-
Ibadan 1	-	-	-	-	-	-	50.00	-	-	-	-	50.00
Ibadan 2	19.23	26.92	-	19.23	3.85	7.69	-	-	-	23.08	-	-
Ibadan 3	14.29	-	-	28.57	-	-	-	-	42.86	14.29	-	-
Ibadan 4	8.70	-	39.13	-	-	-	-	-	21.74	30.43	-	-
Ijebu Igbo 1	75.00	-	-	-	-	25.00	-	-	-	-	-	-
Ijebu Igbo 2	-	-	-	-	-	-	100.00	-	-	-	-	-
Ijebu Igbo 3	-	-	-	100	-	-	-	-	-	-	-	-
Ijebu Igbo 4	-	-	-	25.00	-	-	25.00	25.00	-	25.00	-	-
Akure 1	77.78	11.11	-	11.11	-	-	-	-	-	-	-	-
Akure 2	20.00	-	20.00	13.33	6.67	6.67	-	-	-	33.33	-	-
Akure 3	33.33	-	-	-	-	-	66.67	-	-	-	-	-
Akure 4	77.78	11.11	-	11.11	-	-	-	-	-	-	-	-
Ado Ekiti 1	27.27	18.18	-	9.09	13.64	-	-	-	-	31.82	-	-
Ado Ekiti 2	-	-	-	76.92	-	-	7.69	-	-	15.38	-	-
Ado Ekiti 3	30.00	-	-	50.00	-	-	-	-	-	-	20.00	-
Ado Ekiti 4	50.00	-	-	10.00	20.00	-	-	-	-	20.00	-	-

Key: Not present

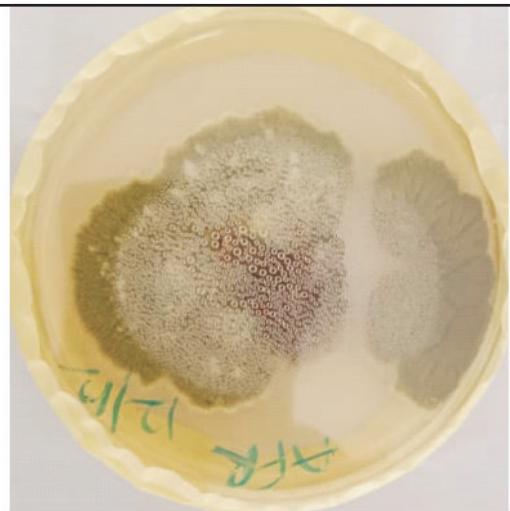
-:

Table 2: Percentage occurrence (%) of fungi associated with stored cocoa beans obtained in wet season across South-West, Nigeria

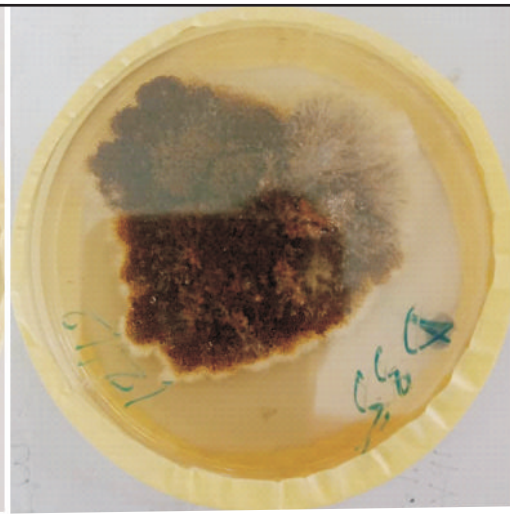
Location (Cocoa store)	**Storage fungi**											
	Aspegillus flavus	*A. parasiticus*	*A. nidulans*	*A. niger*	*A. ochraceous*	*A. fumigatus*	*Fusarium* spp.	*Pythium* spp.	*L. theobromae*	*Rhizopus* spp.	*Neurospora* spp.	*Penicillium* spp.
Ile Ife 1	-	-	-	-	-	-	50.00	-	50.00	-	-	-
Ile Ife 2	46.67	-	-	-	-	-	26.67	-	-	26.67	-	-
Ile Ife 3	62.50	-	-	-	-	-	-	-	-	37.50	-	-
Ile Ife 4	36.36	-	-	9.09	-	18.18	27.27	-	-	9.09	-	-
Ibadan 1	35.71	-	-	-	42.86	-	-	-	14.29	7.14	-	-
Ibadan 2	9.09	-	-	-	-	-	-	-	9.09	81.81	-	-
Ibadan 3	20.00	-	-	40.00	-	-	-	20.00	-	-	20.00	-
Ibadan 4	8.33	-	-	8.33	-	-	-	58.33	8.34	8.33	-	8.33
Ijebu Igbo 1	88.24	-	-	-	-	-	11.76	-	-	-	-	-
Ijebu Igbo 2	27.27	-	-	18.18	-	-	-	18.18	36.36	-	-	-
Ijebu Igbo 3	36.36	-	-	27.27	18.18	-	-	-	-	18.18	-	-
Ijebu Igbo 4	38.46	-	-	30.77	-	-	-	-	-	15.38	-	15.38
Akure 1	-	-	-	-	-	-	-	-	77.78	-	22.22	-
Akure 2	50.00	-	-	-	-	-	-	-	-	40.00	10.00	-
Akure 3	-	-	-	-	50.00	-	-	-	-	50.00	-	-
Akure 4	-	-	-	-	50.00	-	-	-	-	50.00	-	-
Ado Ekiti 1	-	-	-	-	-	-	-	-	-	31.25	6.25	-
Ado Ekiti 2	25.00	-	-	-	-	-	50.00	-	-	25.00	-	-
Ado Ekiti 3	25.00	-	-	-	-	-	-	-	75.00	-	-	-
Ado Ekiti 4	33.33	-	-	-	-	-	-	-	66.67	-	-	-

Key:

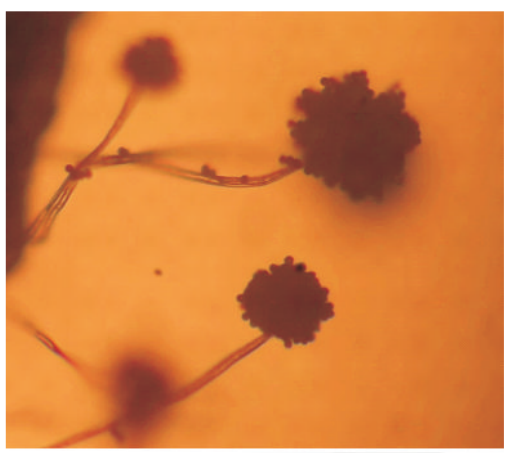
-: Not present



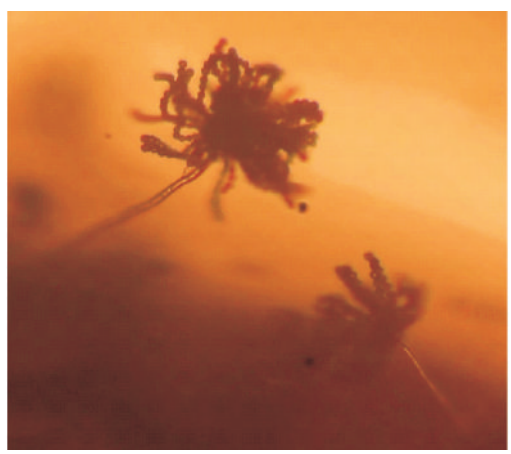
1a: *Aspergillus flavus* strain isolated during wet season



1b: *A. ochraceous* strain isolated during dry season



1c: Photomicrograph of *A. flavus* isolated during wet season



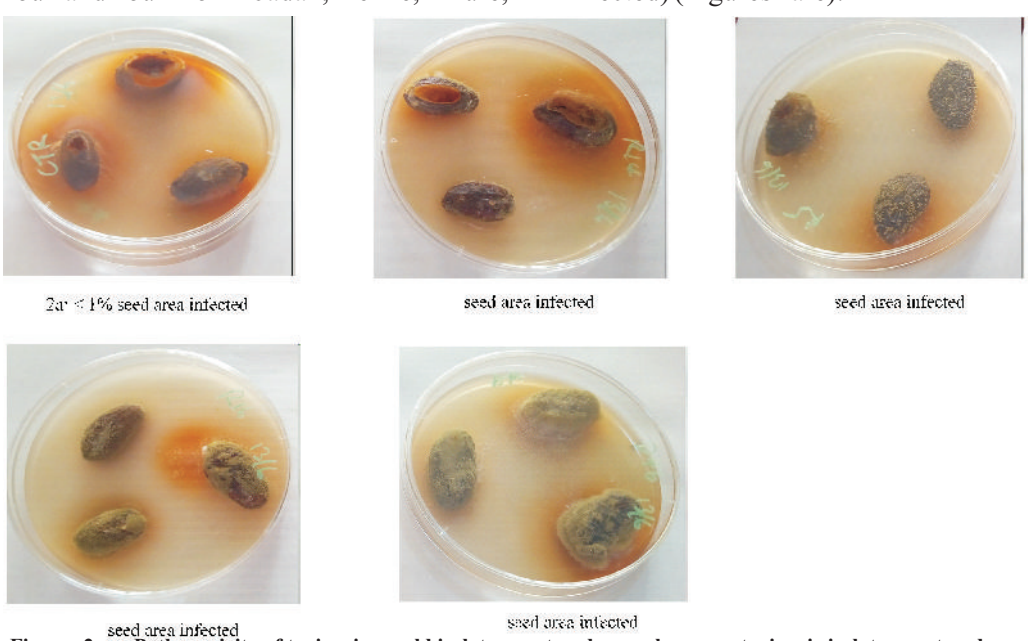
1d: Photomicrograph of *A. ochraceous* isolated during dry season

Figures 1a-d: Culture plates and photomicrographs of *Aspergillus* spp. isolated during wet and dry seasons of the year

Pathogenicity Testing

The pathogenicity of infection of the moulds- *Aspergillus* spp. isolated from stored cocoa beans during the dry season of the year are presented in Table 3. A total of 100 *Aspergillus* isolates were recovered from both dry season and wet season cocoa beans samples. Out of the 100 isolates, 46 were obtained from dry season samples, while 54 were from the wet season samples (Tables 3 and 4). Out of the dry season isolates, 11, 16, four, seven and eight isolates of *Aspergillus* were obtained from Ibadan, Ile Ife, Akure, Ijebu Igbo and Ado Ekiti cocoa samples in Oyo, Osun, Ondo, Ogun and Ekiti States, respectively (Table 3). Only two isolates (obtained from Ile Ife and Ado Ekiti samples) showed high pathogenicity with more than 50% of the seed area infected, while 23 (six, nine, two, three and three) from samples obtained from Ibadan, Ile Ife, Akure, Ijebu Igbo and Ado Ekiti, respectively showed moderate to low pathogenicity (11-50% seed area infected). Twenty isolates (five, five, two, four and four from Ibadan, Ile Ife, Akure, Ijebu Igbo and Ado Ekiti samples, respectively) showed weak pathogenicity (1-10% seed area infected). One *Aspergillus* isolate obtained from Ile Ife sample however was not pathogenic (less than 1% seed area infected) (Figures 2a-e).

The pathogenicity of *Aspergillus* spp. isolated from wet season stored cocoa beans samples are shown in Table 4. Out of the 54 wet season isolates, 12, 11, 5, 23 and three were obtained from Ibadan, Ile Ife, Akure, Ijebu Igbo and Ado Ekiti samples, respectively. Only one isolate (obtained from Ibadan sample) showed high pathogenicity, while 14 (five, two, three, two and two from Ibadan, Ile Ife, Akure, Ijebu Igbo and Ado Ekiti samples, respectively) showed moderate to low pathogenicity. Thirty-eight isolates (six, nine, two, twenty and one from Ibadan, Ile Ife, Akure, Ijebu Igbo and Ado Ekiti samples, respectively) however showed weak pathogenicity. Only one isolate (obtained from Ijebu Igbo sample) was not pathogenic (less than 1% seed area infected) (Figures 2a-e).



Figures 2a-e: Pathogenicity of toxigenic mould isolates on stored cocoa beans on toxigenic isolates on stored cocoa beans

	Location	Isolate	Pathogenicity rating		Location	Isolate	Pathogenicity rating
1	Ibadan 2	*Aspergillus flavus*	3	24	Ile Ife 2	*A. flavus*	3
2	Ibadan 3	*A. flavus*	2	25	Ile Ife 2	*A. flavus*	3
3	Ibadan 4	*A. flavus*	3	26	Ile Ife 1	*A. flavus*	3
4	Ibadan 4	*A. flavus*	2	27	Ile Ife 3	*A. flavus*	3
5	Ibadan 3	*A. flavus*	3	28	Akure 1	*A. flavus*	4
6	Ibadan 3	*A. flavus*	2	29	Akure 1	*A. flavus*	3
7	Ibadan 2	*A. flavus*	3	30	Akure 1	*A. flavus*	2
8	Ibadan 3	*A. ochraceous*	2	31	Akure 1	*A. flavus*	2
9	Ibadan 4	*A. flavus*	2	32	Ijebu Igbo 3	*A. ochraceous*	2
10	Ibadan 2	*A. flavus*	4	33	Ijebu Igbo 1	*A. flavus*	2
11	Ibadan 1	*A. flavus*	3	34	Ijebu Igbo 2	*A. ochraceous*	3
12	Ile Ife 3	*A. flavus*	2	35	Ijebu Igbo 4	*A. flavus*	3
13	Ile Ife 1	*A. flavus*	2	36	Ijebu Igbo 3	*A. flavus*	2
14	Ile Ife 1	*A. flavus*	3	37	Ijebu Igbo 1	*A. flavus*	2
15	Ile Ife 1	*A. ochraceous*	2	38	Ijebu Igbo 4	*A. flavus*	3
16	Ile Ife 1	*A. flavus*	3	39	Ado Ekiti 3	*A. ochraceous*	3
17	Ile Ife 1	*A. flavus*	2	40	Ado Ekiti 4	*A. flavus*	2
18	Ile Ife 3	*A. ochraceous*	3	41	Ado Ekiti 4	*A. flavus*	2
19	Ile Ife 2	*A. flavus*	4	42	Ado Ekiti 1	*A. flavus*	2
20	Ile Ife 2	*A. flavus*	2	43	Ado Ekiti 3	*A. ochraceous*	5
21	Ile Ife 1	*A. flavus*	1	44	Ado Ekiti 1	*A. flavus*	3
22	Ile Ife 3	*A. flavus*	3	45	Ado Ekiti 3	*A. ochraceous*	2
23	Ile Ife 2	*A. ochraceous*	5	46	Ado Ekiti 1	*A. flavus*	2

Key:

1: < 1% seed area infected (Not pathogenic); 3: 11-25% seed area infected (Low pathogenicity); 5: > 50% seed area infected (High pathogenicity)

2: 1-10% seed area infected (Weak pathogenicity); 4: 26-50% seed area infected (Moderate pathogenicity);

Table 4: Pathogenicity of wet season toxigenic isolates on stored cocoa beans

	Location	Isolate	Pathogenicity		Location	Isolate	Pathogenicity rating
1	Ibadan 1	*Aspergillus flavus*	3	28	Akure 2	*A. flavus*	3
2	Ibadan 1	*A. ochraceous*	2	29	Ijebu Igbo 2	*A. flavus*	2
3	Ibadan 4	*A. flavus*	2	30	Ijebu Igbo 2	*A. flavus*	3
4	Ibadan 1	*A. flavus*	4	31	Ijebu Igbo 1	*A. flavus*	2
5	Ibadan 1	*A. flavus*	2	32	Ijebu Igbo 1	*A. flavus*	2
6	Ibadan 1	*A. ochraceous*	5	33	Ijebu Igbo 2	*A. flavus*	2
7	Ibadan 4	*A. flavus*	3	34	Ijebu Igbo 1	*A. flavus*	2
8	Ibadan 1	*A. flavus*	2	35	Ijebu Igbo 1	*A. flavus*	2
9	Ibadan 1	*A. flavus*	3	36	Ijebu Igbo 1	*A. flavus*	2
10	Ibadan 1	*A. flavus*	3	37	Ijebu Igbo 2	*A. flavus*	1
11	Ibadan 1	*A. flavus*	2	38	Ijebu Igbo 1	*A. flavus*	2
12	Ibadan 1	*A. ochraceous*	2	39	Ijebu Igbo 1	*A. flavus*	2
13	Ile Ife 2	*A. flavus*	2	40	Ijebu Igbo 1	*A. flavus*	2
14	Ile Ife 2	*A. flavus*	2	41	Ijebu Igbo 1	*A. flavus*	2
15	Ile Ife 2	*A. flavus*	2	42	Ijebu Igbo 1	*A. flavus*	2
16	Ile Ife 2	*A. flavus*	2	43	Ijebu Igbo 1	*A. flavus*	2
17	Ile Ife 2	*A. flavus*	2	44	Ijebu Igbo 1	*A. flavus*	2
18	Ile Ife 3	*A. flavus*	3	45	Ijebu Igbo 1	*A. flavus*	2
19	Ile Ife 2	*A. flavus*	2	46	Ijebu Igbo 1	*A. flavus*	2
20	Ile Ife 3	*A. flavus*	3	47	Ijebu Igbo 1	*A. flavus*	2
21	Ile Ife 3	*A. flavus*	2	48	Ijebu Igbo 1	*A. flavus*	2
22	Ile Ife 2	*A. flavus*	2	49	Ijebu Igbo 3	*A. ochraceous*	2
23	Ile Ife 3	*A. flavus*	2	50	Ijebu Igbo 1	*A. flavus*	2
24	Akure 2	*A. flavus*	2	51	Ijebu Igbo 2	*A. flavus*	3
25	Akure 2	*A. flavus*	4	52	Ado Ekiti 2	*A. flavus*	2
26	Akure 2	*A. flavus*	2	53	Ado Ekiti 3	*A. flavus*	3
27	Akure 2	*A. flavus*	3	54	Ado Ekiti 3	*A. ochraceous*	3

Key:

1: < 1% seed area infected (Not pathogenic); 3: 11-25% seed area infected (Low pathogenicity); 5: > 50% seed area infected (High pathogenicity)

DISCUSSION

The clear dominance by members of the *Aspergillus* species (especially *A. flavus*) and *Rhizopus* spp. in both dry and wet-season cocoa beans samples across the five southwestern States is in agreement with the findings of Guehi *et al.* (10) and Fagbohun *et al.* (9) whose storage moulds isolation work focused on stored cocoa beans collected from the cocoa stores in Ado Ekiti, Nigeria.

Findings of Sánchez-Hervás *et al*., (18) who specifically worked on the Amazon Forastero cocoa beans varieties obtained from Equitorial Guinea, and those of Delgado-Ospina *et al.* (7) who isolated array of storage moulds from sun-dried stored cocoa beans collected at different times and from different locations in Brazil, however only agree with the dominance of *Aspergillus* spp. in stored dry cocoa beans. *Rhizopus* spp. occurred much less frequently in the stored cocoa beans samples worked upon by the authors. This gives a global acceptance to the importance of *Aspergillus* spp. in the storage of dried fermented cocoa beans.

The increased presence of *Lasiodiplodia theobromae* and *Neurospora* sp. in the dried cocoa beans samples collected during the wet season period of the year, though disagreed with the findings of some authors, could be due to the presence of conducive environmental conditions that greatly favour the proliferation of the storage moulds (5). Also, contrary to the findings of Sánchez-Hervás *et al*., (18), Guehi *et al.* (10) and Akinfala *et al.* (1), *Penicillium* spp. were either completely absent in the dry season cocoa beans samples or isolated only in few instances from the wet season samples in this study.

The primary sources of the fungi isolated from the dried stored cocoa beans samples have been reported to be from airborne contamination, particularly during the late periods of fermentation and from different media like fermentation baskets, drying platforms, storage sacks, etc. as well as other postharvest handling practices (4;7).

The varying degree of infections by the different strains of *A. flavus* on the dried fermented cocoa beans samples through the pathogenicity testing in this study, is a confirmation of the findings of many authors that the toxigenic mould is a storage pathogen of the commodity (6; 9). The fungus, like some others, sometimes come in contact with the beans shortly before or during the process of fermentation, and remained as normal mycoflora on the healthy seeds even after drying, and then perpetuate in the seed lots at the advent of favourable environmental conditions (16).

Research findings have shown that *A. flavus* isolates, being storage pathogens of dried fermented cocoa beans, are capable of causing some physiological problems, including nutrient depletion, loss of viability, etc. in the infected cocoa beans (2). This study has discovered that not all strains of *A. flavus* are capable of causing infections on dried fermented cocoa beans either during the wet or dry season of the year.

CONCLUSION

This study showed that Aspergillus spp. and *Rhizopus* spp. dominated storage mould populations in dried fermented cocoa beans obtained from Southwestern States of Nigeria, both in the dry and wet seasons of the year. Most strains of *A. flavus* were consistently associated with dried fermented cocoa beans as storage pathogens during both dry and wet storage environmental conditions. Further studies however need to be conducted towards finding lasting (integrated) solutions to fungal and mycotoxin contamination of dried fermented cocoa beans at storage.

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