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Yam chip food sub-sector: hazardous practices and presence of aflatoxins in Benin

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Abstract

A survey of the sanitary quality, particularly concerning aflatoxin contamination and practices of the dried yam chips food sub-sector was carried out in Benin. Producers and intermediaries of the yam chips food production sub-sector were interviewed and samples collected. Aflatoxin content was assessed by a biochemo-luminescence method on a total of 107 samples. Twenty-three per cent of the samples had aflatoxin contents over the $15\,\mu g\,kg^{-1}$ CODEX standard value for total aflatoxin. Moisture content of whole tuber chips was around 20% when producers stopped drying after 3–6 days. Drying was thus not accomplished, but most producers were unaware of this problem. After storage for 7 months, mean moisture content was around 14%, but 41% of the samples stored in rooms had a moisture content over 15%, levels that are still favourable for mould growth. Most producers, wholesalers and retailers complained about storage problems and particularly about insect proliferation, but less than 15% mentioned mould growth as a problem. Mouldy chips are generally washed and dried again. Very rarely are mouldy chips discarded and lack of moulds is not a quality attribute for dried yam chips. Therefore, there is a risk of chronic exposure to aflatoxin for Beninese yam chips consumers.

Keywords: Aflatoxin; Benin; Yam chips; Drying; Storage

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1. Introduction

Yam (*Dioscorea* spp.) is an important staple food for many people in the yam zone of West Africa (from Guinea to Nigeria). To overcome the high perishability due to their high moisture content and the seasonal nature of their production, yams are processed into dried chips and flour, particularly in Benin and Nigeria (Bricas et al., 1997; Hounhouigan et al., 2003). Amala, the thick paste prepared from dried yam chip flour is thus as much or more consumed than pounded yam (the reference yam dish for most consumers) in the urban areas of both countries: for example, 21% of Cotonou (the largest city of Benin) inhabitants regularly (several times a week) consume amala.

However, dried yam chips may be contaminated with moulds and particularly toxigenic species such as *Aspergillus* spp. as already observed in Nigeria (Adisa, 1985; Adeyanju and Ikotun, 1988). These fungi may produce mycotoxins and particularly aflatoxins that can cause serious health hazards to humans (Miller, 1995). *Aspergillus* spp. toxigenic species are present in all agroecological zones of Benin (Sétamou et al., 1997) and the presence of aflatoxin in Beninese maize has been reported, the level of which is influenced by storage practices and conditions (Hell et al., 2000a, b). However, no study has looked at aflatoxin presence and distribution in dried yam chips. The objectives of this study were to evaluate aflatoxin distribution at important steps in the entire food sub-sector of dried yam chips in Benin and to identify practices that can increase their presence.

2. Materials and methods

2.1. Survey and collection of samples

The survey was carried out between July and August 2000 in the central and southern part of Benin. All members of the dried yam chips sub-sector were interviewed, which represented more than 150 interviews: 32 producers, 19 wholesalers, 30 retailers, 36 restaurant owners and 37 consumers. The interviewed producers were located in the South (8), Centre (9) and North (15) zones of the main dried yam chips production area (Northern Guinea Savanna). They were selected by chance meetings on visits to the villages. Concerning the intermediaries and end users, the survey was conducted in the urban areas around Parakou, the main city of the area where dried yam chips are widely sold and consumed. Participants were involved by chance meetings in the main districts. At the end of the interview, a 100–500 g sample of dried yam chips (at least three tubers) was collected from their stock. Yam chips were also collected from 9 wholesalers, 10 retailers, 8 restaurant owners and 8 consumers in the same area in a different period (May–June 2001). In addition, traditional sun-drying processes were monitored in late February and early March of 2001 in 13 locations; 3 whole tubers, or pieces and heads, or peelings were weighed daily. At the end of the drying period, as determined by the producer, they were collected and taken for further analysis to the laboratory. All samples were stored at 4°C until analysis.

2.2. Analyses

Dry matter was determined by heating at 105°C to constant weight. Aflatoxin B1 content was determined by using an enzyme-linked immunosorbent assay (ELISA; Aflatoxin Ridascreen kit, R-Biopharm, Darmstadt, Germany) associated with a luminescent viewer. Samples were ground in a centrifuge mill (Retsch, Haan, Germany) with a 0.2 mm screen. Of the homogenised flour obtained, 10 g was poured into a 100 ml flask to which 12.5 ml of water and then 20 ml of methanol were added. The flask was corked and placed on a magnetic stirrer for 30 min at ambient temperature. An aliquot (1 ml) was then centrifuged (7000 *g* for 5 min) and diluted 7 times with the buffer of the ELISA kit. 50 µl of the diluted sample was placed in a well coated with antibodies to mouse antibodies of the immunoplate of the kit. 50 µl of aflatoxin-peroxidase conjugate and of anti-aflatoxin antibodies were added, at the same time, followed by incubation for 30 min. Free and enzyme labelled (peroxidase conjugate) aflatoxins competed for the antibody binding sites of the anti-aflatoxin antibodies, which themselves were bound simultaneously on the immunoplate. Any unbound enzyme conjugate was then removed by pouring the liquid out of the well then rinsing three times with 250 µl of purified water. 100 µl of an equal mixture of substrate and Luminogen (Supersignal, Pierce) was immediately added and the well placed in the cell of a luminometer. The emitted light was measured immediately for 1 min; it was inversely proportional to the aflatoxin concentration in the sample. Aflatoxin content was calculated from the standard curve obtained with the aflatoxin B1 standard solutions (0, 50, 150, 450, 1350 $ng\,l^{-1}$) of the kit. The kit used is not specific for aflatoxin B1 and cross reactivity is of 100%, 200%, 15% and 16% for aflatoxins B1, B2, G1 and G2, respectively, according to the manufacturer. The aflatoxin content calculated from the aflatoxin B1 standard curve was thus a total value.

3. Results

3.1. Yam chips processing

Yam chips are processed by smallholders in Benin. Seventy-five per cent of the surveyed producers produced less than 2 tons of dried yam chips a year. Twenty-five per cent were women who did not have their own yam fields, but bought the raw material from other farmers. Farmers processed whole tubers from their own fields, whereas women can also utilise pieces and heads of tubers and peelings (Fig. 1) that are discarded materials from fresh tuber use in cooking. One half of wholesalers and retailers sold both whole dried yam chips and chip pieces. Most producers processed yam chips directly in the field. Yam tubers are hand-peeled, pre-cooked at around 65°C (Akissoé et al., 2001) in the presence of colouring leaves (in particular from *Tectona grandis* L.), and then sun-dried for less than one week, generally on plant residues from yam cultivation (Fig. 2). Yam chips are generally processed in the dry season when the dry wind (Harmattan) is blowing, i.e. from December to February.

One-third of the producers reported encountering difficulties during processing. The main problem cited by producers (13 out of 36) was the difficulty in adjusting the pre-cooking temperature; under-pre-cooking leads to a blackish colour at the centre of dried yams, whereas

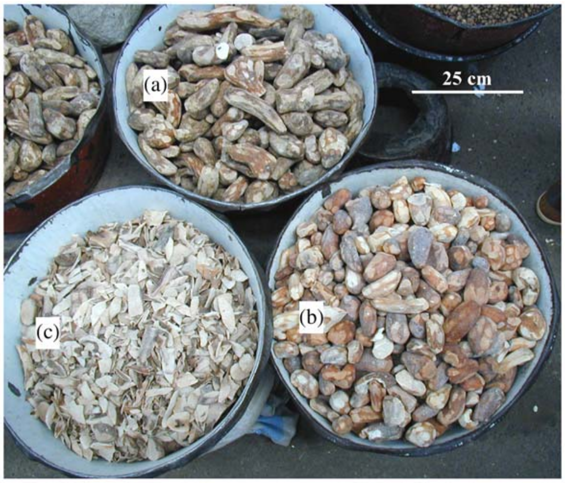

Fig. 1. Traditional dried yam chips: (a) whole tubers, (b) pieces and heads, (c) peelings.

Fig. 2. Yam chips drying in a field.

over pre-cooking gives a hard and sticky tuber that is very difficult to dry. Only 3 producers complained about problems during drying.

Sun-drying was monitored at farmer level at the end of the processing period (January–February) without interfering with the normal process. Thirteen monitoring actions were performed during this period, covering 3 weeks. Air relative humidity was around 20% day and night during the first week but varied between 30% and 80% during the second and third week. For whole tubers, sun-drying was stopped after 3–6 days, depending on the producer; tubers had a moisture content of between 16% and 23% (wet basis, wb). Actually, drying was not complete

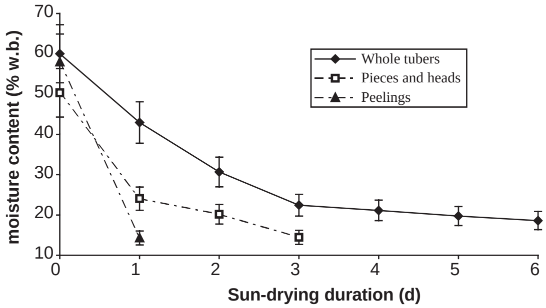

Fig. 3. Changes in moisture content of yam during traditional sun-drying.

and it can be extrapolated from the drying kinetic curve (Fig. 3) that at least 10 days would be necessary to lower tuber moisture content to 14% (wb). Drying was much quicker in the case of pieces and heads of tubers or of peelings, taking 3 days or 1 day, respectively.

3.2. Storage, insect control and product quality

Fifty per cent of the producers, but less than 25% of the wholesalers and retailers stored yam chips for more than three months. Most of them, particularly producers, stored yam chips on the mud or cement floor in a room in their houses that often did not have any windows (Table 1). Some wholesalers had closed, cemented warehouses and retailers also store yam chips in open sheds in the market places. Dried yam chips were generally stored in jute bags (80%). They were also stored in heaps (mainly by producers) or in bowls (by retailers).

Of the interviewees 63% complained about storage problems. The major problem was insect proliferation (85% of those complaining of storage problems, representing 55% of interviewees), whereas less than 15% mentioned mould growth. Thirty-five per cent of the interviewees treated their stock against insects; but only 25% of producers who stored for the longer period. Forty per cent of the insecticidal products used can be considered to be dangerous to the consumers (field insecticides such as DDT or cotton insecticides, and petroleum) and no more than 19% of interviewees treated dried yam chips with the recommended insecticide (Sofagrain®). Six per cent of the producers used field insecticides as storage protectant of yam chips, whereas 17% of the retailers used petroleum. Seventy-five per cent of the yam chips that showed mould growths were still sold after washing and/or re-drying or regrading (Table 2). Less than 12% of interviewees who had mouldy yam chips reported discarding them. It was noticed that the frequency of discarding increased dramatically as the intermediary's contact with consumers increased.

For all trade participants of the yam chips food sub-sector, the major quality criterion of dried yam chips was the whiteness of their inner part, which indicated that pre-cooking was correctly performed (Table 3). The next most important criterion was the red colour of the yam chips that showed the use of colouring plant material during pre-cooking. Light weight of the yam chip, cited by 13% of interviewees, tended to indicate that drying was complete. Actually, sanitary criteria represented less than 10% of the quality attributes cited by members of the yam chips food sub-sector and among them the absence of moulds was cited only once.

Table 1
Frequency of storage structures used for dried yam chips

	Producer (32)[a]	Wholesaler (19)	Retailer (30)	Total (81)
Room	69%	42%	73%	64%
Silo	25	0	0	10
Warehouse	6	37	3	12
Open shed	0	0	23	9
No response	0	21	0	5

[a] Number of interviewees.

Table 2
Handling and using of mouldy yam chips

	Producer[a] (32)	Wholesaler (19)	Retailer (30)	Restaurant owner (36)	Total (117)
Washing and drying	81%	74%	50%	28%	56%
Drying	9	11	10	11	10
Regrading and selling	3	5	30	0	9
Household consumption	6	11	3	3	5
Feeding to animals	0	0	0	8	3
Discarding	0	0	7	33	12
No response	0	0	0	17	5

[a] Percentage of responses (number of interviewees).

Table 3
Quality attributes of dried yam chips

	Producer[a] (32)	Wholesaler (19)	Retailer (30)	Restaurant owner (36)	Total (117)
White inner part	69%	74%	77%	78%	74%
Light weight	16	0	3	25	13
Red color of outer part	25	26	20	8	19
Lack of insects	3	0	10	8	6
Lack of pesticide	0	5	0	0	1
Lack of mould	0	0	0	3	1

[a] Percentage of interviewees; multiple responses possible (number of interviewees).

3.3. Moisture content and aflatoxin contamination

Moisture content of yam chips collected in 2000 after 7 months of storage in traditional conditions ranged between 12.0% and 18.2% (wb) with a mean value of 14.7% (wb). It depended on the storage structure; 41% of yam chip samples collected from store rooms had a moisture content higher than 15% (wb), against 11% of yam chips stored in other conditions (Table 4).

Table 4
Percentage of dried yam chips having water content over 15% (wb)

Storage structure	Producer[a] (32)	Wholesaler (19)	Retailer (30)	Total (81)
Room (52)	44	37	41	41
Other (29)	33	0	13	11

[a] Number of samples.

Table 5
Aflatoxin content ($\mu g\,kg^{-1}$) of dried yam chips at three collection dates

	Collection date			
	[a]07–08/2000 (49)[b]	[c]02–03/2001 (23)	[d]05–06/2001 (35)	Total (107)
Mean value	14	4	36	19
Minimum	2	0	0	0
Maximum	200	15	170	200

[a] Samples collected from producers and intermediaries.
[b] Number of samples.
[c] Samples collected from producers immediately after drying.
[d] Samples collected from intermediaries, only.

Table 6
Frequency distribution[a] of aflatoxin levels in dried yam chip food sub-sector

Aflatoxin content	Producer ($N = 23$)[b]	Producer ($N = 10$)[c]	Wholesaler ($N = 19$)[c,d]	Retailer ($N = 19$)[c,d]	Restaurant owner ($N = 18$)[c,d]	Consumer ($N = 18$)[c,d]	Total ($N = 107$)
<4 ppb	74	0	0	5	0	17	20
Between 4 and 15 ppb	22	70	63	58	78	67	57
>15 ppb	4	30	37	37	22	17	23

[a] Percentage of samples belonging to aflatoxin content class.
[b] Samples collected from producers immediately after drying (02–03/2001).
[c] Samples collected from producers and intermediaries (07–08/2000).
[d] Samples collected from intermediaries, only (05–06/2001).

Moisture content varied from 11.0% to 18.8% (wb) with a mean value of 13.8% (wb) for the collection of May–June 2001, i.e. after 5 months of storage.

The mean value for overall aflatoxin content was 19 $\mu g\,kg^{-1}$ (Table 5) and 25 samples out of 107 (23%, Table 6) had a total aflatoxin content above the 15 $\mu g\,kg^{-1}$ CODEX standard value for total aflatoxins, whereas 86 (80%) were above the European standard (4 $\mu g\,kg^{-1}$) for total aflatoxins in cereals intended for direct human consumption (Otsuki et al., 2001). The mean aflatoxin level was particularly high for the third collection: only 4 out of 35 samples were safe according to the European standard whereas 20 exceeded the CODEX standard. In contrast, the mean value was quite low for the second collection conducted immediately after drying, most samples having a total aflatoxin level lower than the European standard and only one reaching the 15 μg kg^{-1} CODEX standard value. Most samples of the first collection were in an intermediate position between the European and CODEX standards. No obvious pattern for aflatoxin content could be seen across the yam chip food sub-sector (Table 6). Similar frequencies of aflatoxin levels were observed from producers to consumers: after 5 (third collection) to 7 (first collection) months storage, 23% of yam chips exceeded the CODEX standard for total aflatoxins.

4. Discussion

The aflatoxin content was determined using a commercial ELISA kit coupled with a chemiluminescent viewer instead of the commercial colorimetric procedure. This is a very rapid procedure without any cleaning step of the extracts. Results were not checked by HPLC or TLC but extracts were diluted (7 times with buffer) before application onto the immunoplate which is known to eliminate nonspecific reactions from ELISA systems (Hongyo et al., 1992).

A substantial presence of aflatoxins was revealed in dried yam chips of Benin. This was evident from a restricted sampling plan (107 samples) and in spite of being obliged to use rather small samples (100–500 g) from each source. This result was however expected, as infection of dried yam chips by *Aspergillus* spp. has already been noted in neighbouring Nigeria (Adisa, 1985; Adeyanju and Ikotun, 1988), where the same processing technology is used and similar ecological conditions prevail. In addition, *Aspergillus* spp. has been found to be widely distributed in the Northern Guinea Savanna of Benin (Sétamou et al., 1997), the area where dried yam chips are produced.

In the present study 23% of yam chip samples had aflatoxin contamination levels of more than the 15 μg kg^{-1} CODEX standard. In comparison, the percentage of maize samples harvested in 1994 and 1995 in the same climatic zone (Northern Guinea Savanna of Benin) having an aflatoxin level over 20 μg kg^{-1} (Hell et al., 2000a) was about 12%. The aflatoxin levels observed in dried yam chips represent a risk of chronic exposure to aflatoxin because 'amala', the thick paste derived from the chips, is one of the staple foods in these countries (Bricas et al., 1997; Hounhouigan et al., 2003). Incidentally, the presence of aflatoxin in yam chips indicates that yam could be a more favourable medium than cassava for the production of aflatoxins as no aflatoxin was detected by Wareing et al. (2001) in dried cassava products that were, however, infected by *Aspergillus* spp.

The aflatoxin level increases during storage since freshly dried yam chips (collection of 02–03/2001) had much lower levels of aflatoxins than chips stored for five to seven months (collections 05–06/2001 and 07–08/2000, respectively). An increase of aflatoxin contamination with storage period has already been observed by Hell et al. (2000a, b) on maize harvested and stored in Benin. Aflatoxin production may be favoured during storage by climatic conditions. Indeed, air maximum relative humidity exceeds 80% from April to November in the area of production. Such levels are highly favourable for fungal growth and mycotoxin production (Richard-Molard et al., 1985). This should lead to an equilibrium moisture content of dried yam chips between 16% and 17% (wb; Zohry, 2000) and indeed, a large proportion of yam chips stored for 6 months had a moisture content greater than 15% (wb) which is much higher than the 13–13.5% value recommended for long time storage of cereals (Abdullah et al., 2000). In addition, moisture content of dried yam chips was higher when stored in poorly ventilated domestic rooms. This could be due to the sorption of the water vapour generated by human respiration by chips. Similarly, aflatoxin risk increased in maize when grains were stored under the roof of the house as reported by Hell et al. (2000a).

Presence of aflatoxins may also be linked to insect proliferation, cited by the interviewees as the main storage problem. Indeed, insect proliferation favoured mould growth and aflatoxin production on stored products by opening new infestation pathways, by vectoring fungal spores and by increasing moisture content (Sétamou et al., 1997; Franzolin et al., 1999; Hell et al., 2000b). One of the possible strategies to reduce aflatoxin contamination is thus the use of appropriate storage insecticides (Hell et al., 2000a). But, the survey revealed that less than 30% of interviewees treated their stored products with insecticides whereas 55% complained about insect attacks. Similar results were reported by Hell et al. (2000a) for stored maize in the same area where more than 40% of farmers complained about insect damage but less than 20% treated their stocks with insecticides.

Another risk linked to insects, is the use of dangerous insecticidal products. During the survey, 6% of producers admitted the use of inappropriate field or cotton insecticides to treat yam chips whereas previous surveys in Benin reported a much higher frequency of insecticide misuse on yam chips and maize (Hounhouigan and Akissoë, 1997; Vernier et al., 1999; Meikle et al., 1999; Hell et al., 2000a).

When producers stop drying after 3–6 days, the residual moisture content measured in whole yam chips was high (around 20% wb) as already observed by Hounhouigan and Akissoë (1997). Drying of whole yam chips is thus not complete, but most producers (9 out of 12) were not aware of this problem. Actually, drying continues during storage as moisture content of yam chips stored for 5–7 months was around 14% (wb). The time necessary to attain this value is however unknown. In addition, storage conditions are not favourable to a rapid decrease of moisture content (heaps or bags and poorly ventilated rooms), but are very favourable to mould growth and insect proliferation. A parallel can be drawn to the storage of maize ears in the traditional "Ago" structure, a poorly aerated traditional store, used in the same area. In the "Ago", Hell et al. (2000a) found that it takes 3 months to lower maize grain moisture content from 20% (at harvest) to 14% (safe condition). During this period stored products are at risk of fungal development and aflatoxin production. Thus, pre-storage in a "crib" that can favour desiccation may reduce risk of aflatoxin contamination for yam chips as is observed for maize ears (Udoh, 2000). The use of pieces of tubers and the practice of slicing sometimes encountered when large tubers are processed may also be a solution to this problem by decreasing the drying period to 2–3 days (Kayode et al., 2004).

The health risk linked to toxigenic moulds is almost unknown by all intermediaries in the yam chip food sub-sector. Only one interviewed person cited presence of moulds as a quality and buying criterion. More generally, sanitary criteria (presence of insects, pesticide residues or moulds) are underestimated, representing less than 10% of responses about quality criteria of yam chips whereas at the same time, 55% of producers, wholesalers and retailers complained about insects and moulds. This discrepancy has already been observed on dried cassava products. Most cassava wholesalers and retailers prefer buying unmouldy chips, while 65% of the consumers will accept mouldy chips to eat (Wareing et al., 2001).

The aflatoxin risk increases all along the dried yam food sub-sector chain as mould growth and aflatoxin production increases with the age of the chips. In addition, almost no trader will throw away mouldy chips. They rather try to hide the problem by washing and drying. This is not a solution as *Aspergillus* spp. and aflatoxin are distributed throughout the chip (Bassa et al., 2001). They will not be eliminated by simple washing, but mould growth will conversely be favoured during this second period at high moisture content.

5. Conclusion

Presence of aflatoxin at levels hazardous to human health has been found in dried yam chips produced in Benin. This may be linked in particular to an incomplete drying process at the outlet, followed by inappropriate storage conditions. Several actions may contribute to reducing this risk. These include increasing the duration of the drying period or decreasing the size of the chip, the use of aerated pre-storage facilities (such as the ‘‘crib’’ recommended and used for maize), increasing aeration of the storage structures, insecticide treatment of stores and stored products, and an awareness campaign to inform people about the risk of commercialising and consuming mouldy food.

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