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Quality and safety assessment of sun dried meat product (kundi) from Ibadan, Oyo state, Nigeria

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Abstract: This study was carried out to assess the quality and safety assessment of sun dried meat product (kundi) from markets in Ibadan, Oyo State, Nigeria. Sun dried meat (kundi) (50) samples were collected from ten major markets in Ibadan. The samples were analyzed for the proximate composition, rancidity indices and the presence of aflatoxigenic fungi and mycotoxins. The results revealed that the mean moisture, protein, fat, crude fiber, ash and carbohydrate contents (%) of fried fish samples ranged from 10.23 ± 0.11 to 12.63 ± 0.16, 61.98 ± 1.10 to 64.47 ± 1.68, 9.76 ± 0.10 to 12.27 ± 0.17, 0.92 ± 0.04 to 1.37 ± 0.09, 0.98 ± 0.02 to 1.76 ± 0.09 and 10.24 ± 0.12 to 13.94 ± 0.17 respectively. The values of PV (meq peroxide/kg), FFA (%), TBA (mg Mol/kg), TVB-N (mg N/kg) and trimethylamine value (mg N/kg) and were in the range of 17.23 ± 0.20–19.94 ± 0.33, 2.91 ± 0.13–3.90 ± 0.20, 2.07 ± 0.11–2.96 ± 0.19, 15.97 ± 0.21–18.74 ± 0.30 and 1.93 ± 0.10–2.91 ± 0.19. A total of nine fungal strains including: *Aspergillus flavus*, *Aspergillus niger*, *Aspergilus tamarri*, *Fusarium compacticum*, *Fusarium oxysporum*, *Fusarium sacchari*, *Penicillium chrysogenum*, *Penicillium citrinin* and *Penicillium oxalicum* were isolated from the samples. All the samples were contaminated with aflatoxin and majority were contaminated with deoxynivalenol (DON). The total aflatoxin and DON in the samples ranged from 1.39 ± 0.07 to 3.66 ± 0.18 ppb and 0.06 ± 0.02 to 0.39 ± 0.10 ppm. The levels of mycotoxins contamination were within the maximum permissible level of 20 ppb set for aflatoxin by USFDA. The presence of mycotoxigenic fungi and mycotoxin levels in the sun-dried

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PUBLIC INTEREST STATEMENT

This research work is of interest to food processors, food vendors, regulatory agents, government officials, non-governmental organizations and the public. This would help in quality control and in reducing sharp practices by processors and retailers and give better and safer product.

meat (kundi) samples is of public health concern and proper attention is needed for the control of quality, adequate preservation and storage of the product before sales and consumption to prevent food poisoning.

Subjects: Bioscience; Environment & Agriculture; Food Science & Technology

Keywords: sun-dried; quality; mycotoxins; safety; meat; assessment

1. Introduction

Meat, generally is excellent in supplying high quality protein, vitamins and mineral salts (Kramiliah, Pearson, & Tauber, 1973). Similarly, it has been reported as ideal for the growth of a wide range of spoilage bacteria (May et al., 2003), accounting to a great extent why it is perishable. In the world today, traditionally processed meat products are consumed in different countries, amongst which is the meat delicacy called 'Banda, or Kundi' (Vilar, Garcia Fontan, Prieto, Tornadijo, & Carballo, 2000).

Banda, or kundi or tinko is one of the most popular traditional hard-smoked or sun-dried meat products, mostly from rejected cattle and discarded transport beasts (donkeys, horses, camels, buffaloes and elephants), widely consumed in Africa. The word "banda" is of northern origin while similar names in Igbo and Yoruba are "kundi" and "tinko", respectively. Banda is the most commonly produced traditional African dried meat. The production processes involve the use of carcass, cutting, cooking for 15–30 min, drying and sun-drying or smoking for about 18–30 h, cooling, storage and packaging in sacks and jute/mat bags. Banda is a stable product with a shelf-life of 6–12 months or even up to two years under ambient temperature (Idufueko, 1984; Okonkwo & Obanu, 1984). "Banda" is an ideal source of animal protein and its inclusion in a balanced diet should go a long way towards improving nutrition in Nigeria. It also adds to the ecstatic appeal of the food. The high quality of meat protein in Banda is well established and is essential in the maintenance of a healthy population (Okonkwo, 1987). Microbial quality of meat products plays an important role in an increasing public health issue all over the world. Microbial and mycotoxin analysis must be carried out in "banda" aimed for human consumption because of its high mycoflora contamination due to inadequate handling practices, as well as fungi contamination during preservation.

Mycotoxins are a group of secondary metabolites produced by filamentous fungi which may contaminate foods, feeds or the raw materials used to produce them. They also produce mycotoxicoses in humans and animals. The genera of mycotoxigenic fungi are mainly represented by *Aspergillus*, *Penicillium* and *Fusarium*, but *Trichoderma*, T*richothecium* and *Alternaria* are also important as food contaminants or pathogens for plants, among others (Moss, 1994; Smith & Moss, 1985). Mycotoxins, particularly aflatoxins (AFTs) and ochratoxin A (OTA) pose a significant threat to human health. Aflatoxins are potent carcinogens and, in association with hepatitis B virus, are responsible for many thousands of human deaths per annum, mostly in non-industrialized tropical countries (Shephard, 2006). Ochratoxin A is a probable human carcinogen and it was reported to cause urinary tract cancer and kidney damage in people from Eastern Europe. Exposure to OTA seems to be the biggest hazard correlated to microscopic fungi for the European consumers of cereals (European Comission, 2006). Fumonisins are a group of *Fusarium* mycotoxins occurring worldwide in maize and maize-based products destined for human and animal consumption. Fumonisins are known to be the cause of equine leuko-encephalomalacia (a brain disease that is often fatal) and porcine pulmonary oedema syndrome (swelling of lungs and thorax), both associated with the consumption of corn-based feeds.

This research was carried out to investigate the quality and safety of street-vended sun-dried meat product (kundi) from different markets in Ibadan, Oyo State, Nigeria.

2. Materials and methods

2.1. Materials

2.1.1. Sample collection

A total of 50 sun-dried meat (kundi) samples were collected from 10 major markets in Ibadan, Oyo State, Nigeria by purposive sampling method. They were subsequently packaged in sterile polyethylene bags labeled properly and taken to the laboratory for analyses.

2.1.2. Proximate analysis

The proximate composition of all sun-dried meat (kundi) samples were carried out in triplicates according to the standard method (AOAC International, 2000).

2.1.3. Physico-chemical analysis

Kent pH meter (model 7020, Kent Ind. Measurement Ltd., Surrey, UK) was used to measure the pH of the sun-dried meat in triplicates, employing 10 g of sun-dried meat (kundi) homogenized in 10 ml of distilled water. The rancidity indices of all the samples were carried out in triplicates according to the standard method AOAC International (2000). All chemicals used in this study were of the analytical grade unless stated otherwise.

2.1.4. Enumeration of fungi

Appropriate dilutions of Sabouraud dextrose agar plates (Oxoid) were poured over 1 ml of the sun-dried meat (kundi) homogenate and dilutions. Plates were incubated at 25°C for 3 days and then colonies were counted and reported as fungal count/ml.

2.1.5. Determination of aflatoxigenic fungi

Determination of aflatoxigenic fungi was carried out using the method of Davis, Iyer, and Diener (1987). Pure fungal isolates were cultured on coconut agar medium (CAM). The plates were incubated for 3 days at 28°C. Production of an orange-yellow pigmentation by the mycelium was observed for toxigenic isolates prior to the production of blue fluorescence on the reverse side of the colony under UV light (365 nm).

Toxigenic fungal isolates were also determined using a modified method of (Atanda, Akpan, & Enikuomehin, 2006). Pure matured fungal isolates were cultured on palm kernel agar (PKA). Aflatoxigenic fungi were detected by the production of yellow pigmentation and a blue fluorescence of agar under UV light (365 nm).

2.1.6. Determination of mycotoxins in the samples

Quantitative determination of total aflatoxin and deoxynivalenol (DON) in sun-dried meat (kundi) samples using enzyme linked immunosorbent assay (ELISA). The mycotoxins analysis were carried out using commercially available immunoassay kit Veratox test-NEOGEN Crop, Lansing, MI was used.

2.2. Sample preparation and extraction

The collected sun-dried meat (kundi) samples were ground into powdery form with the use of high speed blender, thoroughly mixed together and made into composite, followed by weighing on an electronic scale. Five grams of sun-dried meat (kundi) samples was put into an extraction cup. Twenty-five milliliters of 70% methanol was added for aflatoxin, while 25 ml of sterile distilled water was added for the DON, the extraction cup was covered and manually shaken for 3 min; the mixture was then allowed to settle down. The extract was filtered by pouring 5 ml through a Whatman filter syringe, and filtrate was collected for further analysis.

2.3. Test procedure

The number of dilution strips required for both the samples and the standards were placed in a micro-well strip holder. Equal numbers of antibody coated strip were also placed in a micro-well strip holder. Using a multipurpose channel pipettor 100 µL of the conjugate was introduced into each of the dilution well. Hundred microliters of the sample were placed in the dilution well containing the conjugate base. The multipurpose pipettor was used to mix the sample by carefully pipetting it upwards and downwards three times. Hundred microliters of the mixture was immediately transferred into antibody coated plate and incubated for 5 min at room temperature. The antibody coated plates were later decanted and washed five times with distilled water. Hundred microliters portion of the substrate was then put into the antibody coated plate and incubated. A stop solution of 100 µL was introduced into each antibody coated plate. The micro-well strips were subsequently analysed using a micro-well reader using a 630 nm filter. Concentration of mycotoxins was read and calculated using Neogen's Veratox software.

2.4. Concentration and production of aflatoxin by Aspergillus species and DON by Fusarium species

Aspergillus and *Fusarium* isolates identified on PDA were sub cultured in duplicate on YESA consisting of (Yeast extract 4.0 g, KH_2PO_4 1 g, $MgSO_4 \cdot 7H_2O$ 0.5 g, sucrose 20.0 g and agar 15 g per liter) and incubated at 28°C for 21 days to evaluate the aflatoxin and DON production (Kana et al., 2013). Aflatoxin and DON was extracted from approximately 5 g of YESA with fungi colonies in 25 mL of 70% methanol and sterile distilled water respectively using the standard ELISA extraction protocol essentially described by the kit manufacturer (NEOGEN Crop, Lansing, MI, USA). Aflatoxin and DON was quantified using ELISA KIT (Veratox for quantitative analysis of total aflatoxin and DON test-NEOGEN Crop, Lansing, MI).

3. Data analysis

Data were means of triplicates ± standard deviation. Statistical significance of the data among the samples was determined by analysis of variance (ANOVA) with a level of confidence of 5% ($p \leq 0.05$). Duncan multiple range test was used to compare significant differences between the means. For this analysis IBM SPSS Statistics (version 20.0) was employed.

4. Results and discussion

The results of the analysis revealed that the moisture and protein contents (%) of sun-dried meat (kundi) samples (Table 1) were in the range of 10.23 ± 0.11–12.63 ± 0.16 and 61.98 ± 1.10–64.47 ± 1.68 respectively while the fat and crude fiber contents (%) of sun-dried meat (kundi) samples were in the range of 9.76 ± 0.10–12.27 ± 0.17 and 0.92 ± 0.04–1.37 ± 0.09 respectively. The ash

Table 1. Proximate composition of sun-dried meat (kundi) samples from major markets in Ibadan, Oyo State

Major markets	Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)
Academy	12.63 ± 0.16^{a}	61.47 ± 1.08^{d}	11.44 ± 0.14^{b}	0.92 ± 0.04^{e}	1.58 ± 0.07^{b}	11.96 ± 0.13^{d}
Apata	11.28 ± 0.13^{c}	63.12 ± 1.16^{b}	10.93 ± 0.12^{c}	1.06 ± 0.06^{d}	1.71 ± 0.09^{a}	11.90 ± 0.13^{d}
Bodija	12.17 ± 0.16^{b}	62.18 ± 1.12^{c}	11.19 ± 0.14^{b}	1.21 ± 0.08^{b}	1.23 ± 0.04^{d}	12.02 ± 0.14^{c}
Challenge	10.49 ± 0.11^{d}	64.32 ± 1.43^{a}	9.76 ± 0.10^{d}	0.98 ± 0.05^{e}	1.36 ± 0.05^{c}	13.09 ± 0.16^{b}
Dugbe	11.31 ± 0.13^{c}	61.98 ± 1.10^{d}	10.04 ± 0.11^{c}	1.11 ± 0.07^{c}	1.62 ± 0.08^{b}	13.94 ± 0.17^{a}
Gate	10.72 ± 0.11^{a}	63.71 ± 1.21^{b}	11.36 ± 0.14^{c}	1.37 ± 0.09^{a}	0.98 ± 0.02^{e}	11.86 ± 0.13^{d}
Oja-Oba	10.38 ± 0.11^{b}	64.19 ± 1.39^{a}	10.98 ± 0.12^{c}	1.09 ± 0.06^{c}	1.41 ± 0.06^{c}	11.95 ± 0.13^{d}
Oje	12.01 ± 0.16^{bc}	62.94 ± 1.13^{c}	9.82 ± 0.10^{d}	0.94 ± 0.04^{e}	1.27 ± 0.04^{d}	13.02 ± 0.16^{b}
Ojoo	10.62 ± 0.11^{d}	62.81 ± 1.13^{c}	11.64 ± 0.14^{b}	1.26 ± 0.08^{b}	1.48 ± 0.06^{c}	12.19 ± 0.14^{c}
Sango	10.23 ± 0.11^{d}	64.47 ± 1.68^{a}	12.27 ± 0.17^{a}	1.03 ± 0.06^{d}	1.76 ± 0.09^{a}	10.24 ± 0.12^{e}

Notes: Data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

and carbohydrate contents (%) of sun-dried meat (kundi) samples (Table 1) were in the range of 0.98 ± 0.02–1.28 ± 0.09 and 10.24 ± 0.12–13.94 ± 0.17 respectively.

The sun-dried meat (kundi) samples have high amount of protein and fat. This can help in complementing the high carbohydrate-based diets of the people of Nigeria and also reduce malnutrition especially among the vulnerable groups of children and pregnant women. This agreed with findings of (Adeyeye et al., 2015; Oladejo & Adebayo-Tayo, 2011). The relatively high mineral content, ash and crude fiber can be attributed to an increase in the dry matter content per unit weight following drying process. (da Silva, 2002) and da Silva et al. (2008) reported similar results for smoked fish.

The results of rancidity indices in this study revealed that the PV (mEq peroxide/kg) and the free fatty acids (FFA) value (%) of sun-dried meat (kundi) samples (Table 2) were in the range of 17.23 ± 0.20–19.94 ± 0.33 and 2.91 ± 0.13–3.90 ± 0.20 respectively. The TBA values (mg Mol/kg) of sun-dried meat (kundi) samples (Table 2) was in the range of 2.07 ± 0.11–2.96 ± 0.19 while the total volatile base- nitrogen (TVB-N) (mg N/kg) of sun-dried meat (kundi) samples (Table 2) was in the range of 15.97 ± 0.21–18.74 ± 0.30 respectively. The trimethylamine value (TMA) (mg N/kg) of sun-dried meat (kundi) samples (Table 2) was in the range of 1.93 ± 0.10–2.91 ± 0.19.

The peroxide values are very high and very close to the recommended value of between 20 and 40 mgeq peroxide/kg for rancid taste to begin in dried or smoked meat and fish. FFA value is the number of mg of potassium hydroxide required to neutralize the free acid in a gram of the sample. The result of FFA is often expressed as percentage of free acidity. The FFA values obtained were very high and this suggests that the level of fat decomposition in the sun dried meat is high. These values are very close to the value for rancidity detection in dried and smoked meat and fish. The values of PV and FFA obtained from this research work do not agreed with findings of some of the previous work of Adeyeye et al. (2015); da Silva (2002); da Silva et al. (2008); Oladejo and Adebayo-Tayo (2011). This difference may be due to difference in processing methods or mode and period of storage of the product at retail level. The thiobarbituric acid value (TBA) is used to assess the degree of fish spoilage especially in fatty fish. The TBA test measures a secondary product of lipid oxidation, malonaldehyde (da Silva, 2002). The TBA values of sun-dried meat (kundi) samples were also high. The TBA (2.07 ± 0.11–2.96 ± 0.19 mg TBA/kg) is slightly above the range specified by USFDA. This showed the level of fat oxidation in the sun-dried meat. TVB-N is related to protein breakdown and is an index of meat/fish spoilage (da Silva, 2002). The legislative standard for TVB-N include: 20 mg N/100 g for fresh meat/fish, 30 mg N/100 g stale meat/fish and 40 mg N/100 g for meat/fish

Table 2. Quality indices of sun-dried meat (kundi) samples from major markets in Ibadan, Oyo State, Nigeria

Major markets	Peroxide value (PV) (m Eq peroxide/ kg)	Free fatty acid (FFA) %	Thiobarbituric acid (TBA) (mg Mol/kg)	d Total volatile b base-nitrogen (TVB-N) (mg N/kg)	Trimethyl amine value (mg N/kg)
Academy	19.42 ± 0.29^{b}	3.31 ± 0.18^{c}	2.91 ± 0.19^{a}	17.81 ± 0.27^{c}	2.68 ± 0.17^{b}
Apata	18.71 ± 0.24^{c}	3.28 ± 0.17^{d}	2.07 ± 0.11^{d}	18.22 ± 0.29^{b}	2.91 ± 0.19^{a}
Bodija	17.23 ± 0.20^{d}	3.54 ± 0.19^{b}	2.72 ± 0.15^{c}	15.97 ± 0.21^{g}	2.69 ± 0.17^{b}
Challenge	19.88 ± 0.30^{a}	3.19 ± 0.16^{e}	2.96 ± 0.19^{a}	16.54 ± 0.22^{f}	2.46 ± 0.14^{d}
Dugbe	19.39 ± 0.28^{b}	2.91 ± 0.13^{g}	2.77 ± 0.15^{c}	17.82 ± 0.27^{c}	2.18 ± 0.12^{f}
Gate	19.17 ± 0.27^{c}	3.11 ± 0.15^{d}	2.91 ± 0.19^{a}	17.63 ± 0.25^{d}	2.59 ± 0.19^{c}
Oja-Oba	19.94 ± 0.33^{a}	3.28 ± 0.17^{d}	2.09 ± 0.11^{d}	16.92 ± 0.24^{e}	1.93 ± 0.10^{g}
Oje	18.73 ± 0.24^{c}	3.04 ± 0.14^{f}	2.93 ± 0.19^{a}	15.56 ± 0.20^{h}	2.45 ± 0.14^{d}
Ojoo	17.66 ± 0.22^{d}	3.16 ± 0.16^{e}	2.83 ± 0.17^{b}	16.81 ± 0.23^{e}	2.31 ± 0.13^{e}
Sango	18.81 ± 0.25^{c}	3.90 ± 0.20^{a}	2.84 ± 0.17^{b}	18.74 ± 0.30^{a}	2.19 ± 0.12^{f}

Notes: Data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

that is unfit for human consumption but can be used for animal feed (da Silva, 2002; Food & Agriculture Organization (FAO), 2004). In this study, the total volatile base-nitrogen (TVBN) of sun-dried meat (kundi) samples was 15.97 ± 0.21–18.74 ± 0.30 although but was within the range of legislative standard for TVB-N which is 20mgN/100 g for fresh meat/fish. This suggests that the level of protein decomposition or breakdown in all the samples was not high and within acceptable limit. TMA of 1.93 ± 0.10–2.91 ± 0.19 mg N/kg for sun-dried meat (kundi) samples are within the range of <3 mg N/100 g for fresh meat/fish, >8 mg N/100 g for spoiled meat/fish and >5 mg N/100 g for doubtful quality specified.

The total fungi count was high in which the highest was recorded in sun-dried meat (kundi) samples obtained from samples from Academy Market and the lowest from Oje Market (Table 3). A total of nine fungi strains were obtained from the sun-dried meat samples. The fungi were identified *as Aspergillus flavus*, *Aspergillus niger*, *Aspergilus tamarri*, *Fusarium compacticum*, *Fusarium oxysporum*, *Fusarium sacchari*, *Penicillium chrysogenum*, *Penicillium citrinin* and *Penicillium oxalicum* (Table 4).

The isolation of these genera in the samples agreed with the findings of some researchers who isolated similar organisms from smoked-dried fish, dried meats, rice, "garri", and peanut meal and maize (Adebayo-Tayo, Adeyemi, Odeniyi, & Olaseinde, 2015; Adebayo-Tayo, Onilude, & Patrick, 2008; Jonathan et al., 2013; Kana et al., 2013; Oladejo & Adebayo-Tayo, 2011; Somorin, Bankole, Omemu, & Atanda, 2011).

Different fungal strains were isolated from the sun-dried meat (kundi) samples which are of major public health concern. A major public health risk with long term health implication is the contamination of food and feed with fungi that may be aflatoxigenic (Bucci, Kansen, & Labord, 1990). The low water activity as a result of sun-drying reduces the competitive effects of most bacteria. Several physical factors including moisture, humidity, ambient temperature, storage time, pH and oxygen affect fungal growth and mycotoxins production in sun-dried meat (Kaaya, Kyamuhangire, & Kyamanywa, 2006). Majority of the fungal organisms isolated and identified are widely distributed in nature and have their habitat mostly in the soil and decaying matter (Raper & Fennell, 1965). They are able to contaminate food and cause infection.

The isolated fungi can be classified as storage fungi. The storage fungi could have contaminated the sun-dried meat (kundi) samples during any of the phases of processing. The storage fungi includes *A. niger*, *A. flavus*, *Aspergillus tamarii*, the others are *P. chrysogenum*, *Penicillium citrinum*, *Penicllium oxalicum*, *Rhizopus* sp. (Bankole & Adebanjo, 2003). The fungal species that colonize the sun-dried meat (kundi) samples must have been present in the atmosphere in the form of spores during the

Table 3. Total fungi count (×10³ cfu/g) of the sun-dried meat samples (Kundi) obtained from major markets in Ibadan, Oyo State, Nigeria

Major markets	Total fungal count
Academy	$4.6 \pm 0.20 \times 10^{3a}$
Apata	$3.3 \pm 0.17 \times 10^{3c}$
Bodija	$3.6 \pm 0.18 \times 10^{3b}$
Challenge	$3.6 \pm 0.18 \times 10^{3b}$
Dugbe	$2.8 \pm 0.15 \times 10^{3d}$
Gate	$2.1 \pm 0.11 \times 10^{3f}$
Oja-Oba	$1.8 \pm 0.10 \times 10^{3f}$
Oje	$3.3 \pm 0.17 \times 10^{3c}$
Ojoo	$2.6 \pm 0.13 \times 10^{3e}$
Sango	$2.5 \pm 0.12 \times 10^{3e}$

Notes: Data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

Table 4. Detection of aflatoxigenic fungi from sun-dried meat samples (kundi) obtained from major markets in Ibadan, Oyo State, Nigeria

Sources/Isolates	Fungus strain	Detection media	
		PKA	CAM
Academy market			
ACD 1	*P. citrinium*	−	−
ACD 2	*F. compacticum*		
ACD 3	*A. niger*	−	−
ACD 4	*A. flavus*	+	+
ACD 5	*P. citrinum*	−	−
Apata market		−	−
APT 1	*P. citrinum*	−	−
APT 2	*F. solani*		
APT 3	*A. tamarii*	−	−
APT 4	*A. niger*	−	−
APT 5	*A. flavus*	+	+
Bodija market			
BOD 1	*A. flavus*	+	+
BOD 2	*P. oxalicum*	−	−
BOD 3	*A. tamarii*	−	−
BOD 4	*A. niger*	−	−
BOD 5	*F. oxysporum*	−	−
Challenge market		−	−
CHL 1	*F. sacchari*		
CHL 2	*A. tamarii*	−	−
CHL 3	*A. flavus*	+	+
CHL 4	*P. citrinum*	−	−
CHL 5	*P. citrinum*	−	−
Dugbe market			
DUG 1	*A. niger*		
DUG 2	*A. flavus*	+	+
DUG 3	*A. niger*	−	−
DUG 4	*A. niger*	−	−
DUG 5	*A. niger*	−	−
Gate market			
GAT 1	*P. citrinium*	−	−
GAT 2	*F. compacticum*		
GAT 3	*A. niger*	−	−
GAT 4	*A. flavus*	+	+
GAT 5	*P. citrinum*	−	−
Oja-Oba market		−	−
OJB 1	*A. flavus*	+	+
OJB 2	*F. solani*		
OJB 3	*A. tamarii*	−	−
OJB 4	*A. niger*	−	−
OJB 5	*P. citrinum*	−	−

(*Continued*)

Table 4. (*Continued*)

Sources/Isolates	Fungus strain	Detection media	
		PKA	CAM
Oje market			
OJE 1	*F. oxysporum*	−	−
OJE 2	*P. oxalicum*	−	−
OJE 3	*A. flavus*	+	+
OJE 4	*A. niger*	−	−
OJE 5	*F. oxysporum*	−	−
Ojoo market			
OJO 1	*F. sacchari*	−	−
OJO 2	*A. flavus*	+	+
OJO 3	*P. citrinum*	−	−
OJO 4	*P. citrinum*	−	−
OJO 5	*P. citrinum*	−	−
Sango market			
SAN 1	*A. niger*		
SAN 2	*A. niger*	−	−
SAN 3	*A. niger*	−	−
SAN 4	*A. niger*	−	−
SAN 5	*A. flavus*	+	+

processing or gained entrance during storage period as a result of inadequate storage facilities as well as in the market and also during transportation. Majority of these sun-dried meat (kundi) samples are kept close to agricultural commodities which are more susceptible to fungal contamination and mycotoxins production and therefore there is also cross contamination (Adebayo-Tayo et al., 2015). Post-processing handling of dried and smoked protein products is not properly done. The sun-dried meat (kundi) samples were observed to be put on dirty sacks on the floor at the markets. They are stored in poorly ventilated and generally dirty environment, where houseflies contaminate them very much with dirt from the surrounding environment (Adebayo-Tayo et al., 2015).

Aflatoxigenic fungi isolated from the sun-dried meat (kundi) samples obtained from major markets in Ibadan were detected using CAM and PKA Medium. All *A. flavus* strains showed to be capable of producing aflatoxins.

The detection and quantification of total aflatoxin in the sun-dried meat (kundi) samples obtained from different markets in Ibadan are shown in Table 5. Aflatoxin was detected in all the sun-dried meat (kundi) samples and the aflatoxin ranged from 5.90 ± 0.11 to 9.48 ± 0.20 ppb. The highest concentration was recorded in the sun-dried meat (kundi) sample obtained from Oja-Oba Market and the lowest concentration was recorded in sun-dried meat (kundi) sample obtained from Bodija Market.

The detection and quantification of DON in parts per million (ppm) in sun-dried meat (kundi) samples obtained from major market in Ibadan are shown in Table 6. The DON concentration in the contaminated sample ranged from 0.09 ± 0.01 to 0.67 ± 0.08 ppm. The highest DON concentration was recorded in the sun-dried meat (kundi) samples obtained from Academy Market and the lowest concentration was recorded in sun-dried meat (kundi) sample obtained from Oje Market.

The production and concentration of aflatoxin by *A. flavus* isolated from sun-dried meat (kundi) samples in Ibadan showed that all the *Aspegillus flavus* produced aflatoxin which indicates they are all toxigenic strains of *A. flavus*. The highest concentration was recorded in the isolate code BOD

Table 5. Detection and quantification of total aflatoxin (ppb) in sun-dried meat (kundi) samples from major markets in Ibadan, Oyo State

Major markets	Total aflatoxin (ppb)
Academy	8.61 ± 0.17^{c}
Apata	6.13 ± 0.12^{h}
Bodija	5.90 ± 0.11^{i}
Challenge	8.74 ± 0.19^{b}
Dugbe	7.39 ± 0.14^{f}
Gate	7.86 ± 0.15^{e}
Oja-Oba	9.48 ± 0.20^{a}
Oje	6.93 ± 0.13^{g}
Ojoo	8.71 ± 0.18^{b}
Sango	8.26 ± 0.16^{d}

Notes: Data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

Table 6. Detection and concentration of DON in sun-dried meat (kundi) samples from major markets in Ibadan, Oyo State

Major markets	Deoxynivalenol (DON) (ppm)
Academy	0.67 ± 0.08^{b}
Apata	0.43 ± 0.07^{c}
Bodija	0.38 ± 0.05^{d}
Challenge	0.44 ± 0.07^{c}
Dugbe	0.40 ± 0.06^{c}
Gate	0.82 ± 0.09^{a}
Oja-Oba	0.24 ± 0.03^{e}
Oje	0.09 ± 0.01^{g}
Ojoo	0.16 ± 0.02^{f}
Sango	0.27 ± 0.04^{e}

Notes: Data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

having 3.66 ± 0.18 ppb obtained from Bodija Market as shown in Table 7 while the lowest was obtained from the isolate code OJO having 1.39 ± 0.07 ppb obtained from Ojoo Market.

The *Fusarium* spp. were assayed for the production and concentration of DON. Some of the *Fusarium* spp. produced DON. The highest concentration was recorded in the isolate code OJO having 0.39 ± 0.10 ppm obtained from Ojoo Market as shown in Table 8 while the lowest was obtained from the isolate codes ACD, BOD and DUG having 0.06 ± 0.02 ppb obtained from Academy, Bodija and Dugbe Markets.

The detection of aflatoxigenic mould in the sun-dried meat (kundi) samples is in agreement with the work of Gautam, Gupta, and Soni (2012) who reported that aflatoxigenic fungi were screened in rice, also with Sekar, Yumnam, and Ponmurugan (2008) in which aflatoxigenic fungi were screened in dried fruits and grains. Kana et al. (2013) also detected aflatoxigenic fungi in food (grains and maize) and poultry feeds.

All the *A. flavus* isolates in this study were all toxigenic. The occurrence of aflatoxin in the sun-dried meat (kundi) samples may be due to contamination of the samples by the toxigenic strains of *A. flavus.* Aflatoxin contamination occurs when aflatoxigenic species of *A. flavus* group successfully colonize the sample, grow in it and produce aflatoxins as secondary metabolite. Incidence of aflatoxins in other food products such as smoked-dried fish, smoked-dried frog samples, dried yam

Table 7. Production and concentration of aflatoxin by *A. flavus* isolated from sun-dried meat (kundi) samples from major markets in Ibadan, Oyo State

Major markets	Isolate code	Detection of aflatoxin	Concentration (ppb)
Academy	ACD	+	1.68 ± 0.08^{g}
Apata	APT	+	1.92 ± 0.10^{e}
Bodija	BOD	+	2.21 ± 0.11^{d}
Challenge	CHL	+	2.53 ± 0.13^{c}
Dugbe	DUG	+	1.87 ± 0.09^{f}
Gate	GAT	+	3.66 ± 0.18^{a}
Oja-Oba	OJB	+	1.98 ± 0.10^{e}
Oje	OJE	+	2.64 ± 0.15^{b}
Ojoo	OJO	+	1.39 ± 0.07^{h}
Sango	SAN	+	1.81 ± 0.09^{f}

Notes: Data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

Table 8. Production and concentration of DON by *Fusarium* spp. isolated from sun-dried meat (kundi) samples from major markets in Ibadan, Oyo State

Major markets	Isolate code	*Fusarium* isolates	DD[1]	C^2 (ppm)
Academy	ACD	*F. oxysporum*	+	0.06 ± 0.02^{h}
Apata	APT	*F. oxysporum*	+	0.08 ± 0.04^{f}
Bodija	BOD	*F. oxysporum*	+	0.06 ± 0.02^{h}
Challenge	CHL	*F. oxysporum*	+	0.07 ± 0.03^{g}
Dugbe	DUG	*F. solani*	+	0.06 ± 0.09^{h}
Gate	GAT	*F. solani*	+	0.23 ± 0.07^{d}
Oja-Oba	OJB	*F. compacticum*	+	0.19 ± 0.05^{e}
Oje	OJE	*F. compacticum*	+	0.36 ± 0.09^{b}
Ojoo	OJO	*F. compacticum*	+	0.39 ± 0.10^{a}
Sango	SAN	*F. oxysporum*	+	0.28 ± 0.08^{c}

Note: data are means of triplicates ± S.D. Data with the same superscripts are not significantly different at ($p < 0.05$).

chips, has been reported as well (Adebayo-Tayo, Adeyemi, Odeniyi, & Olaseinde, 2015; Adebayo-Tayo, Onilude, & Patrick, 2008; Akinyemi, Adejola, Obasa, & Ezeri, 2011; Hassan, Hassan, El-Shafei, El-Ahl, & Abd El-Dayem, 2011; Makun et al., 2010; Oladejo & Adebayo-Tayo, 2011).

The aflatoxin content obtained from the sun-dried meat (kundi) samples was higher which is not in agreement with the report of Akinyemi, Adejola, Obasa, & Ezeri (2011) and Adebayo-Tayo et al. (2008) who reported a lower level which was between 0.0301–1.150 ppb and 1.5–8.1 ppb. The aflatoxins found to be associated with the sun-dried meat (kundi) samples sold in major markets in Ibadan, were found to be lower than the maximum permissible level that may be toxic to human health. According to the permissible regulatory levels issued by the Food Drug Administration (FDA) of United States (USFDA) the levels for aflatoxin intake for humans is maximum of 20 ppb (Food & Drug Administration, 2000).

The occurrence of DON in the sun-dried meat (kundi) samples may be due to contamination of the samples by the toxigenic strains of *Fusarium* species (Adebayo-Tayo et al., 2015). DON contamination occurs when mycotoxigenic species of *Fusarium* group successfully colonize the sample, grow in it and produce toxins such as DON, zearalenone as secondary metabolite (Adebayo-Tayo et al., 2015). The occurrences of DON in other food products such as in rice, wheat and maize have also been reported by (Duverger et al., 2011). The DON produced were between (0.00 and 0.96 ppm). This was also within the stipulated tolerance limits by the FDA of a maximum of 1.0 ppm.

5. Conclusion

This research work revealed that sun-dried meat (kundi) sold in major markets in Ibadan, Oyo State, Nigeria although has high protein content; however, rancidity indices of the product are poor. In conclusion, sun-dried meat (kundi) sold in major markets in Ibadan are contaminated with mycotoxigenic fungi and mycotoxins which is of public health concern.

This study also concluded that sun-dried meat sold in major markets in Ibadan, Oyo State, Nigeria need proper monitoring as storage and retail practices may have serious impact on the safety of the product.

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References

Adebayo-Tayo, B. C., Onilude, A. A., & Patrick, U. G. (2008). Mycofloral of smoked-dried fishes sold in Uyo, Eastern Nigeria. *World Journal of Agricultural Sciences, 4*, 346–350.

Adebayo-Tayo, B. C., Adeyemi, F., Odeniyi, O., & Olaseinde, K. (2015). Mycoflora, mycotoxin contamination and proximate mineral composition of smoke-dried frog (*Aubria* sp.) (*Konko*) sold in Ibadan, Oyo State, Nigeria. *Turkish Journal of Agriculture-Food Science and Technology, 3*, 894–903.

Adeyeye, S. A. O., Oyewole, O. B., Obadina, A. O., Omemu, A. M., Adeniran, O. E., Oyedele, H. A., & Abayomi, S. O. (2015). Quality and safety assessment of traditional smoked fish from Lagos State, Nigeria. *International Journal of Aquaculture, 5*, 1–9. doi:10.5376/ija.2015.05.0015

Akinyemi, A. A., Adejola, A. Q., Obasa, S. O., & Ezeri G. N. O. (2011). *Aflatoxins in smoked-dried fish sold in Abeokuta, Ogun State, South-west Nigeria*. Proceedings of the Environmental Management Conference, Federal University of Agriculture, Abeokuta.

AOAC International. (2000). *Official methods of analysis* (20th ed.). Gaithersburg, MD: Author.

Atanda, O. O., Akpan, I., & Enikuomehin, O. A. (2006). Palm kernel agar: An alternative culture medium for the rapid detection of aflatoxins in agricultural commodities. *African Journal of Biotechnology, 5*, 1029–1033.

Bankole, S. A., & Adebanjo, A. (2003). Mycotoxins in food in West Africa: Current situation and possibilities of controlling it. *African Journal of Biotechnology, 2*, 254–263.

Bucci, T., Kansen, D. K., & Labord, J. B. (1990). Leukoencephalomalacia and haemorrhage in the brain of rabbits gavaged with mycotoxins Fumonisin B1. *Food Chemistry, 38*, 1900–1903.

da Silva, L. V. A. (2002). *Hazard analysis critical control point (HACCP), microbial safety, and shelf life of smoked blue catfish (Ictalurus furcatus)* (A master of science in food science thesis). The Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College, Baton Rouge, LA.

da Silva, L. V. A., Prinyawiwatkul, W., King, J. M., No, H. K., Bankston, Jr., J. D., & Ge, B. (2008, December). Effect of preservatives on microbial safety and quality of smoked blue catfish (Ictalurus furcatus) steaks during room-temperature storage. *Food Microbiology, 25*, 958–63.

Davis, N. D., Iyer, S. K., & Diener, U. L. (1987). Improved Method of screening for Aflatoxin with a Coconut Agar Medium. *Journal of Applied & Environmental Microbiology, 53*, 1593–1595.

Duverger, F., Bailly, S., Querin, A., Pinson-Gadais, L., Guerre, P., & Bailly, J. D. (2011). Influence of culture medium and incubation time on the simultaneous synthesis of Deoxynivalenol and zearalenone by Fusarium graminearum. *Revenue Medical and Veterinary, 162*, 93–97.

European Comission. (2006). Commission Regulation (EC) No 1881/2006 of 19 December 2006 Setting maximum levels for certain contaminants in foodstuffs (text with EEA relevance). *Official Journal of the European Union, 364*, 5–24.

Food and Agriculture Organization (FAO). (2004). *Worldwide regulations for mycotoxins in food and feed in 2003* (p. 81). Rome: FAO. Food and Nutrition Papers No.

Food and Drug Administration. (2000). *Conference on mycotoxins in animal feeds, grains and food related to human and animal health*. Maryland: Rockville.

Gautam, A. K., Gupta, H., & Soni, Y. (2012). Screening of fungi and mycotoxins associated with stored rice grains in Himachal Pradesh. *International Journal of Theoretical and Applied Sciences, 4*, 128–133.

Hassan, A. A., Hassan, A. M., El-Shafei, H. M., El-Ahl, M. H. S. R., & Abd El-Dayem, R. H. (2011). Detection of aflatoxigenic moulds isolated from fish and their products and its public health significance. *Journal of Nature and Science, 9*, 106–114.

Idufueko, A. S. (1984). Self-sufficiency in animal protein supply under changing economic fortunes. *Nigerian Journal of Animal Production, 11*, 14–21.

Jonathan, S. G., Abdul-Lateef, M. B., & Ayansina, A. D. V. (2013). Fungal and aflatoxin detection in fresh andstored "garri ijebu" (locally processed food). *Report and Opinion, 5*, 13–19.

Kaaya, A. N., Kyamuhangire, W., & Kyamanywa, S. (2006). Factors affecting aflatoxin contamination of harvested maize in the three agro-ecological zones of Uganda. *Journal of Applied Sciences, 6*, 2401–2407.

Kana, R. K., Gnonlonfin, B. G. J., Harvey, J., Wainaina, J., Wanjuki, I., Skilton, R. A., & Teguia, A. (2013). Mycobiota and toxigenicity profile of aspergillus flavus recovered from food and poultry feed mixtures in cameroon. *Journal of Animal and Poultry Science, 2*, 98–107.

Kramiliah, W. E., Pearson, A. M., & Tauber, F. (1973). *Processed meat*. West Pork: AV Pul. Co Inc.

Makun, H. A., Anjorin, S. T., Moronfoye, B., Adejo, F. O., Afolabi, O. A., Fagbayibo, G., Balogun, B. O., & Surajudeen, A. A. (2010). Fungal and aflatoxin contaminations of some human food commodities in Nigeria. *African Journal of Food Sciences, 4*, 127–135.

May, R. D., Margesin, R., Klingbichel, E., Harhugen, E. D., Yenewe, D., Schiner, F., & Mark, I. T. (2003). Rapid detection of meat spoilage by measuring volatile organic compounds by using proto transfer reaction mass spectrophotometry. *Applied Environmental Microbiology, 69*, 4697–4705.

Moss, M. (1994). Hongos micotoxigénicos. In A. R. Eley (Ed.), *Intoxicaciones aliment arias* (pp. 81–101). Zaragoza: Editorial Acribia S.A.

Okonkwo, T. M. (1987). Consumers' preferences for Banda, a Nigerian hot-smoked meat product. *Journal of Food and Agriculture, 1*, 51–55.

Okonkwo, T. M., & Obanu, Z. A. (1984, March, 25-29). *Traditional production of hot-smoked meat in Nigeria. Study of the production technology*. Proceedings 9th Annual Conference of the Nigerian Society for Animal Production, University of Nigeria, Nsukka, Enugu State, Nigeria.

Oladejo, D. A., & Adebayo-Tayo, B. C. (2011). Moulds, proximate mineral composition and mycotoxin contamination of banda ("kundi"/"tinko") sold in Ibadan, Oyo State. *Nigeria A. U. J. Technol, 15*, 32–40.

Raper, K. B., & Fennell, D. I. (1965). *The Genus Aspergillus*. Baltimore, MD: Williams and Wilkins Co.

Sekar, P., Yumnam, N., & Ponmurugan, K. (2008). Screening and charecterization of mycotoxin producing fungi from dried fruits and grains. *Advances Biotechnology, 12*, 15.

Shephard, G. S. (2006). Mycotoxins in the context of food risks and nutrition issues. In D. Barug, D. Bhatnagar, H. P. van Egmond, J. W. vander Kamp, W. A. van Osenbruggen, & A. Visconti (Eds.), *The mycotoxin factbook: Food and feed topics* (pp. 21–36). Wageningen: Wageningen Academic Publishers.

Smith, J. E., & Moss, M. O. (1985). *Mycotoxins: Formation, analysis and significance*. New York, NY: John Wiley and Sons.

Somorin, Y. M., Bankole, M. O., Omemu, A. M., & Atanda, O. O. (2011). Impact of milling on the microbiological quality of yam flours in Southwestern Nigeria. *Research Journal of Microbiology, 6*, 480–487.

Vilar, I., Garcia Fontan, M. C., Prieto, B., Tornadijo, M. E., & Carballo, J. (2000). A survey on the microbiological changes during the manufacture of dry-cured lacon, a Spanish traditional meat product. *Journal of Applied Microbiology, 89*, 1018–1026.

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