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Aflatoxin Contamination of Maize Meal Sold and Consumed in the Three Main Cities of North-Kivu Province of the Democratic Republic of Congo

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Authors' contributions

This work was carried out in collaboration among all authors. Author KMG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JKI and LN managed in study development and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to determine the incidence of aflatoxin contamination of maize meal in the North-Kivu province of D.R.C. The study was conducted in the Beni, Goma and Butembo, the major cities of the North-Kivu province of D.R.C. A multi-stage sampling was applied in all the cities. A total of 30 samples of maize grains were collected.
In each city, five principal open markets were considered and in each, sixteen vendors were chosen randomly. From them, two composite samples of 1.5 kg each of maize grains were collected, there by subdividing randomly the sixteen vendors in two groups of eight vendors. Each composite sample of maize grains collected from eight vendors was milled and then a final composite sample of maize meal of one kilogram was taken for laboratory analysis. 25 samples (10 from Beni, 10 from Goma and 5 from Butembo) where milled raw, while 5 other samples from Butembo where grilled

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before and then where milled. All the samples were analyzed for total aflatoxins using ELISA Kit method according to the manufacturer. Data were subjected to one way ANOVA using Genstat® Discovery 13thEdition at 95% confidence interval (P≤ 0.05). Variable means for measurements showing significant differences in the ANOVA were compared using the LSD. Values were judged to be significantly different by LSD if *P*< 0.05.

The mean levels of aflatoxins in all the maize meals collected in the 3 cities are above 10ppb, the acceptable level of aflatoxins in maize meals for human consumption. The means range between 18.34 and 20.98 ppb, the highest level being in samples collected in Goma city. These results confirm the statement that the maize consumers in all the 3 cities (Beni, Goma and Butembo) are exposed to aflatoxin-contamination as the consumed maize meals are contaminated with aflatoxin at levels surpassing the limits. However, Goma city is highly exposed to aflatoxin contamination.

Keywords: Aflatoxin contamination; maize meal; food safety.

1. INTRODUCTION

In developing countries, the major human problem is not only related to food insecurity but also to food safety issues such as contamination with pathogenic microorganisms and contamination with mycotoxins and especially aflatoxin at acute and chronic toxicity levels [1].

Aflatoxin is a mycotoxin that compromises food security in the most vulnerable groups of people in Africa. It is a fungal infection expressed by the production of secondary metabolites in agricultural products due to Aspergillus flavus, Aspergillus parasiticus and rarely, Aspergillus nomius [2].

Aflatoxins are prevalent in tropical and subtropical food crops, primarily corn, peanuts, oilseeds and tree nuts worldwide [3].

Corn and groundnuts are the more susceptible crops to aflatoxin contamination and constitute the most important causes of aflatoxin exposure in humans with an amount beyond several billion regard to their highly consumption along the world [4].

In D.R.C as in many African regions, maize has become an ideal cereal for diet, feed and for industrial uses, replacing traditional cereals such as sorghum and millets and a substitute to Cassava. The consumption of local maize flour is increasing in the major cities of North-Kivu (Goma, Beni, Butembo) because of the expansion of the population, shortest cultural cycle and the variation of diet [5].

However, maize has been reported to be one of the most prone cereals to aflatoxin contamination [6].

Daily consumption of low doses of aflatoxins in contaminated food may cause chronic aflatoxicosis with low food consumption, retarded growth, destruction of immune-system and liver cancer as consequences [7]. While immediate absorption of high doses of aflatoxins leads to acute aflatoxicosis or even to death [8].

In DRC, the acceptable levels are 5ppb for AFB1 and 10ppb for total aflatoxins [8].

A part from health implications, aflatoxins also has economic implications there by causing post-harvest loses leading to reduced productivity. Moreover, it lowers growth rate of the animals fed on aflatoxin-contaminated grains [9].

In DRC, information on the incidence of aflatoxin, its exposure to both humans and animals and methods of prevention are not well researched; hence, limited information is available as suggested by Kamika and Tekere [10].

Only few studies have been conducted in this area. A comparatively study of Kamika, Tekera and Ngboluo (2016) on the occurrence of aflatoxin in maize collected in the DRC along the food supply chain showed that the contamination of maize is in the range of 70.65 and 98.20%. This study showed that the consumers are exposed to chronic aflatoxin contamination. Therefore, the government intervention is required to provide clear policies on the control of aflatoxin in maize and maize products and institute methods of prevention from field to consumption.

This paper is designed to assess the occurrence of aflatoxin in non-grilled and grilled maize meal collected in the 3 major cities (Beni, Goma and Butembo) of the North-Kivu of the DRC and to determine the moisture content in the samples.

2. METHODOLOGY

2.1Study Site

The study was conducted in 3 major cities of the North-Kivu province (Beni, Goma and Butembo) of DRC, where maize is highly consumed.

2.2 Samples Collection

A multi-stage sampling was applied.

A total of 30 samples of maize grains were collected as follow:

In each city, five principal open markets were considered and in each, sixteen vendors were chosen randomly. From them, two composite samples of 1.5 kg each of maize grains were collected, there by subdividing randomly the sixteen vendors in two groups of eight vendors. Each composite sample of maize grains collected from eight vendors was milled and then a final composite sample of maize meal of one kilogram was taken for laboratory analysis. 25 samples (10 from Beni, 10 from Goma and 5 from Butembo) where milled raw, while 5 other samples from Butembo where grilled before and then where milled.

2.3 Analytical Method

a. Both samples, 25 samples of non-grilled maize meal, 5 samples of grilled maize meal were analyzed for total aflatoxins using ELISA Kit method, mark *helica* biosystems Inc with 96-wells, lot No. AF050818, as manufactured according to the GMP guidelines and quality control test as a unit (Catalogue No. 941AF01M-96).
b. Moisture content was determined using the air oven at 105 °C followed by the desiccation according to the AOCC.

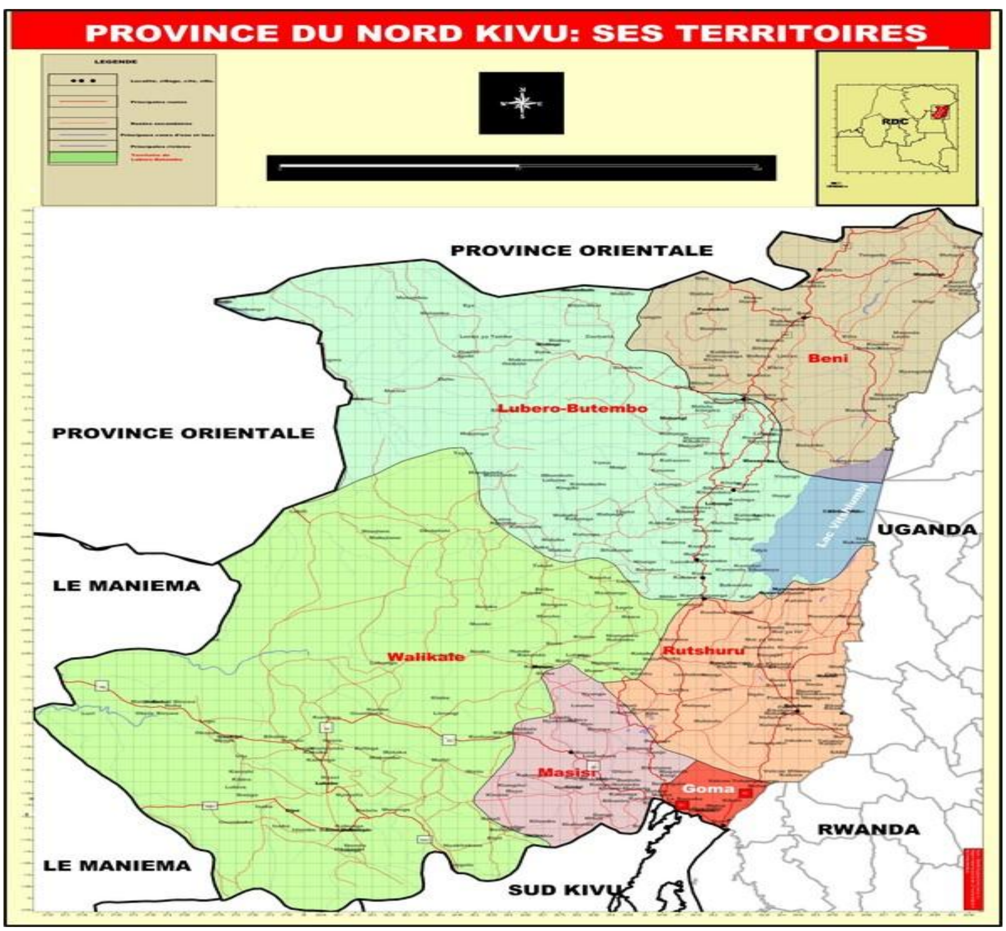

Fig. 1. Map of North Kivu territory/ DR Congo (10/12/2010) by DRC maps

2.4 Data Analysis

Data were subjected to one way ANOVA using Genstat® Discovery 13thEdition at 95% confidence interval (P≤ 0.05). Variable means for measurements showing significant differences in the ANOVA were compared using the LSD. Values were judged to be significantly different by LSD if *P*< 0.05.

3. RESULTS AND DISCUSSION

- As shown in Table 1, all the 10 samples of maize meal collected in Beni city were contaminated with aflatoxin. The aflatoxin contents are significantly different from one sample to another at p<0.05 and significant difference is well seen when the variable means are compared with the LSD of 1.8390. The aflatoxin content ranged between 3.9 and 37.14 ppb with a mean of 20.33 pbb. Out of 10 samples, the aflatoxin contents of 6 or 60% (NG2, 5, 6, 6, 8, 9 and 10) were largely beyond the tolerance of 10 ppb, 2 samples or 20% (NG4 and NG7) were slightly beyond the tolerance while only 2 samples or 20% (NG 1 and NG3) were below the tolerance of 10 ppb for total aflatoxin.
- As in Beni city, all the samples in Goma (Table 1) were also contaminated with aflatoxin and shown a significant difference at p<0.05 when means are compared with the LSD of 0.5959. Values ranged between 3.96 and 47.69 ppb with a mean of 20.29 ppb. 50% of the samples had the aflatoxin content exceeding the tolerance (NG1, 3, 5, 6 and 8) with the highest level of 47.69 and 50% samples had aflatoxin content below the tolerance (NG2, 4, 7, 9 and 10).
  When comes to moisture content, as shown in Table 1, the means of samples collected in Beni city are significantly different from one another when compared with the LSD (1.2295). The values ranged between 11.61 and 13.53% with the mean of 12.41. This difference between samples is probably due to the fact that all the samples were not subjected to the same conditions from the field to the storage. However, although the significant difference, all the samples were within the general recommended storage moisture content level set between 10 – 13% for cereals for aflatoxin prevention [11].
- The means of samples collected in Goma were also significantly different from one another with LSD=0.7139. The minimum and maximum values ranged between 12.40 to 14.62%, respectively. As shown in the same Table 1, only 2 samples (NG4 and NG5) were within the recommended storage moisture content level. All the other 8 samples were slightly above the recommendation for the storage with the highest level of 14.62% for sample 10. As for samples collected in Beni, the difference between samples collected in Goma must rely on the pre as well as post-harvest practices applied by farmers and vendors during storage.
- In Butembo city (Table 2), all the grilled and non-grilled samples were positively aflatoxin contaminated with concentrations ranged between 1.81 and 41.07ppb with a mean of 18.34ppb for non-grilled samples and between 5.56 and 39.2 ppb with a mean of 17.44ppb for grilled samples. Three out of five non-grilled samples (60%) were high than the tolerance (NG2, 3 and 5) while two (40%) where below (GR1vand 4). For grilled samples, also 60% were above the tolerance (GR1, 3 and 5) while 40% where below (GR2 and 4).
  The mean levels of aflatoxins in all the maize meals collected in the 3 cities are above 10ppb, the acceptable level of aflatoxins in maize meals for human consumption. The means range between 18.34 and 20.98 ppb, the highest level being in samples collected in Goma city. These results confirm the statement that the maize consumers in all the 3 cities (Beni, Goma and Butembo) are exposed to aflatoxin-contamination as the consumed maize meals are contaminated with aflatoxin at levels surpassing the limits. However, the high risk of contamination is in Goma city. These outcomes are similar to the ones of Kamika et al.(2016) who conducted a comparatively study assessing the occurrence of aflatoxin in maize samples in DRC throughout the food supply chain and found the aflatoxin contamination of maize ranging between 70.65 and 98.20% which expose consumers to both chronic and acute aflatoxicosis.
- For moisture content in Butembo city (Table 2), the means for all the non-grilled samples were within the recommendation with values ranged between 12.15 to

Table 1. Means of aflatoxin (ppb) and moisture (%) contents of NG maize meal in Beni and Goma

Sample	Mean aflatoxin(ppb)		Mean moisture (%)	
	BENI	GOMA	BENI	GOMA
NG1	3.9± 0.16^{h}	37.84± 0.21^{h}	12.90 ± 0.01^{ab}	13.82 ± 0.07^{bcd}
NG2	34.35± 0.04^{b}	4.88± 0.11^{e}	12.46 ± 0.03^{bc}	13.49± 0.23^{cd}
NG3	8.17± 0.04^{g}	47.69± 0.28^{a}	12.45 ± 0.06^{abc}	13.20± 0.44^{d}
NG4	10.89± 0.07^{f}	5.96± 0.13^{d}	12.29 ± 0.11^{bc}	12.40± 0.01^{e}
NG5	21.1± 0.42^{d}	19.29± 0.38^{b}	11.61 ± 0.24^{c}	12.45± 0.04^{e}
NG6	33.88± 0.64^{b}	28.75± 0.27^{gh}	13.53 ± 0.03^{a}	14.19± 0.47^{abc}
NG7	10.93± 0.49^{f}	8.06± 0.44^{c}	12.56 ± 1.46^{abc}	13.82± 0.51^{bcd}
NG8	37.14± 2.40^{a}	28.92± 0.09^{f}	11.72 ± 0.21^{bc}	13.62± 0.54^{cd}
NG9	26.1± 0.35^{c}	3.96± 0.07^{c}	12.12 ± 0.04^{bc}	14.51± 0.03^{ab}
NG10	16.79± 0.21^{e}	4.49± 0.37^{g}	12.42 ± 0.88^{abc}	14.62± 0.01^{a}
Mean SD	20.33± 11.73	20.98± 15.29	12.41± 0.67	13.61± 0.779

**Mean ± SD (n=30). The mean values with the same superscripts are not significantly different at p<0.05*

Table 2. Means of aflatoxin (ppb) and moisture (%) contents of Grilled and None grilled maize meal in Butembo

Sample	Mean aflatoxin (ppb)	Mean moisture (%)
NG1	1.81± 0.21^{e}	13.16± 0.26^{a}
NG2	41.07± 0.09^{a}	12.55 ± 0.12^{bc}
NG3	36.6± 0.07^{b}	13.05 ± 0.32^{ab}
NG4	6.93± 0.12^{c}	12.15 ± 0.21 ^{c}
NG5	5.29±0.04^{d}	12.38±0.07^{c}
Mean for SD	18.34±17.77	12.66±0.439
GR1	18.58± 0.08^{b}	8.63± 0.46^{b}
GR2	5.56± 0.16^{e}	9.47± 0.41^{a}
GR3	14.09± 0.02^{c}	7.35 ± 0.08^{c}
GR4	9.77± 0.17^{d}	8.56 ± 0.27^{b}
GR5	39.2± 0.06^{a}	8.36 ± 0.08^{b}
Mean for SD	17.44± 12.35	8.47 ± 0.749352

**Mean ± SD (n=30). The mean values with the same superscripts are not significantly different at p<0.05*

13.16%. A significant difference between the samples was shown at LSD=0.5610.

The grilled samples were also significant different from one another with LSD=0.7844 and the moisture contents ranged between 7.35 to 9.47%. The difference is possibly due the difference between the initial moisture contents in the samples before the heat treatment. With these low moisture contents, the grilled maize meals may be kept for long without the risk of fungi growth and aflatoxin production as longer as the environmental conditions (relative humidity and temperature) are well controlled.

4. CONCLUSION

Goma, Beni and Butembo are the major cities of the North-Kivu of DRC in which the consumption of local maize has increased in the population. However, this study has shown that the consumers are at highly exposed to both chronic and acute aflatoxicosis due to the consumption of aflatoxin-contaminated maize and maize products as shown in Tables 1 and 2 where the mean levels of aflatoxins in all the maize meals collected in the 3 cities are above 10ppb, the acceptable level of aflatoxins in maize meals for human consumption. The means range between 18.34 and 20.98 ppb.

Therefore, the government intervention is required to provide clear policies on the control of aflatoxin in maize and maize products and institute methods of prevention from field to consumption.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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