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Assessment of the Aflatoxin Content of Maize Flours Produced in the Commune of Ouagadougou, Burkina Faso

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Abstract

Aflatoxins are toxic metabolites present in various foods, especially when production and conservation do not respect good hygiene practices (GHP). In Ouagadougou, maize flour is produced and sold in different structures by actors who do not always respect GHP. Thus, it is necessary to regularly control the quality of these flours. So, this is carried out with the aim to assess the aflatoxin content of maize flours produced in the municipality of Ouagadougou. For this, twenty-eight (28) samples were collected from households, markets and supermarkets in the city of Ouagadougou. Thus, LC/MS/MS analysis was used to assess the aflatoxin content of the samples. The results obtained reveal the presence of total aflatoxins (AFT) in 78.57% of samples analyzed with levels ranging from 0.89 to 64.25 µg/kg. The prevalence of different types of aflatoxins were 57.14% for aflatoxin B1 (AFB1), 46.43% for aflatoxin B2 (AFB2), 42.86% for aflatoxin G1 (AFG1) and 4.6% for aflatoxin G2 (AFG2). The results also show that 80% and 60% of market samples, 70% and 30% of household samples and 37.5% and 25% of supermarket samples do not comply with European Commission standards for AFT and AFB1 respectively. For all the samples, 60.71% and 42.86% of the samples are compliant according to the limits established by the European Commission (EC) respectively for AFB1 and AFT. Regarding the results obtained, producers and processors must be supervised and trained in GHP for the production of better-quality flours.

Keywords

Aflatoxins, Maize Flour, Sanitaty Quality, LC/MS/MS, Ouagadougou, Burkina Faso

1. Introduction

In West Africa, maize is the main source of caloric intake in the national diet of almost all countries in the Zone [1]. In Burkina Faso, maize ranks second among cultivated cereals, in terms of area, production and consumption [2]. The maize sector is growing, due to the increase in demand from the poultry sector, beverages and other processed products, with production of 1.133.480 and 1.710.898 tons respectively in 2011 and 2019 [3]. However, despite its socio-economic importance, maize faces a sometimes very delicate sanitary quality problem [4]. Like most cereals, maize is subject to contamination by aflatoxins which affect the health of the consumer. Food contamination by aflatoxins affects both natural and processed products such as cereals, oil seeds, dried fruits and products of animal origin [5]. Aflatoxins have a wide range of toxicological and other ill-effects on human life and are of greater public health concern in developing world where need for eating far outweighs other considerations like the safety issues [6]. These aflatoxins represent a major concern for human and animal health since they can cause acute or chronic intoxications which are sometimes fatal due to their various toxic effects [7]. In children especially, aflatoxins lead to stunted growth and suppressed immunity [8]. At economic level, annual crop losses due to aflatoxins alone reach 1.2 billion USD, African countries suffering 38% of these losses, or 450 million USD [9]. In addition, there are also indirect losses, which are more difficult to assess and which are linked to the reduction in productivity of animals receiving feed containing aflatoxins [10].

In Africa, numerous studies have shown the contamination of maize by aflatoxins, sometimes with values exceeding the reference limits [11] [12] [13]. In Burkina Faso, some studies on the evaluation of aflatoxin contents in infant flour have already been carried out [14] [15]. Likewise, the evaluation of the aflatoxin content of *koura-koura* (a product resulting from the processing of peanut) was also carried out [16]. However, the contamination of maize flours of different origins with aflatoxins is not documented. In view of the above information's and regarding the high consumption of maize by the population of Ouagadougou, continuous monitoring of the quality of maize flour is necessary to ensure the safety of this product. So, this study, aims to assess the aflatoxin content of maize flours produced in the municipality of Ouagadougou with the following specific objectives: assess the aflatoxin content of market flours, supermarket flours and household flours.

2. Materials and Methods

2.1. Sampling

A total of 28 samples of maize flours were collected in the Ouagadougou city's. The sampling sites were chosen to cover as many neighborhoods as possible in the commune of Ouagadougou. The collection was carried out in the markets, households and supermarkets. 500 g of each market and household's samples were put in sterile plastic bags and then stored in the laboratory at room temperature. Supermarket samples already packaged in 1000 g bags were collected and then stored under the previous conditions in the laboratory. The sample collection sites and codes are shown in **Table 1**.

2.2. Aflatoxin Assay

Aflatoxin's concentration was measured by LC/MS/MS (liquid chromatography coupled to mass spectrometry) [17].

2.2.1. Extraction

Five (5) g of each flour were introduced into 50 mL falcon tube, then 10 mL of distilled water were added and the whole was briefly vortexed. The solution obtained was left to stand for a few minutes. Ten (10) mL of acetonitrile containing 2% acetic acid were added to the previous mixture, and the whole was vortexed for 5 minutes. Then, 4 g of magnesium sulphate ($MgSO_4$) and 1g of sodium chloride (NaCl) were added and the mixture was vortexed for one minute. The mixture previously obtained was centrifuged for 5 minutes at 4000 rpm.

2.2.2. Purification

After centrifugation, 6 mL of the supernatant was taken for each sample, then introduced into falcon tubes containing each, 1200 mg of magnesium sulphate ($MgSO_4$) and 400 mg of PSA (Primary and Secondary Amine, used to improve

Table 1. Sampling sites and codes of maize flour samples.

Type of sampling	Localization site	Number of samples	Samples code
Market	Pissyyaar	2	MsW1 and MsY1
	Zone 1	1	MsW5
	14 yaar	2	MsW4 and MsY4
	Dassasgho	1	MsY5
	Zagtouli	2	MsW2 and MsY2
	Silmissin	2	MsW3 and MsY3
Household	Zone 1	2	HsW1 and HsY1
	Saaba	2	HsW2 and HsY2
	Secteur 30	2	HsW3 and HsY3
	Tanghin	2	HsW4 and HsY4
	Pissy	2	HsW5 and HsY5
Supermarket	Benogo	1	SsY1
	Zone 1	2	SsW2 and SsY2
	Wayalghin	2	SsW3 and SsY3
	Pissy	2	SsW4 and SsW5
	Zagtouli	1	SsW1

S: sample; M: market; H: Household; S: Supermarket; W: White; Y: Yellow.

purification by removing sugars, fatty acids and organic acids). The mixture obtained was stirred for 1 min and then centrifuged for 5 min at 4000 rpm. Then, the supernatant was extracted using a hydrophobic filter and a syringe. The solutions obtained were introduced into vials.

2.2.3. Aflatoxin Detection and Quantification

HPLC/MS/MS method described by Oplatowska-Stachowiak [17] was used to determine and quantify aflatoxins in homogenized maize flours samples. Standards obtained in powder form were prepared at the concentration 1 mg/mL in the appropriate amount of solvent (MeCN or MeOH) according to the manufacturer's instructions. Different solutions of standards were prepared as calibrants for the instrument to determine the limit of detection of each aflatoxin. The concentrated standard sets were also used for preparing calibrants in matrix. The aflatoxin quantitation was achieved by preparing matrix-matched calibration curves with blank maize flour. The purified products were separated using a C18 column. The mass spectrometry was conducted by using positive electrospray ionization (ESI+) and multiple reaction monitoring (MRM) models. Data acquisition and quantification were performed using Mass Hunter Workstation B.04.01 software (Agilent Technologies).

2.3. Statistical Analyzes

The data collected during this study was subjected to an analysis of variance using XLSTAT-Pro 7.5 version 2019 software. The means of the variables were compared using the Newman Keuls test at the probability level $p = 0.05$.

3. Results and Discussion

3.1. Aflatoxin Content of Flours

3.1.1. Market Flours

The results obtained for the samples taken from the markets are presented in **Table 2**. The results obtained show that aflatoxins B1, B2 and G1 are present in most of the samples of white maize flours with average levels of 7.27 µg/kg, 5.59 µg/kg and 22.62 µg/kg respectively. For yellow maize flour, the levels were 6.14 µg/kg, 12.13 µg/kg and 10.36 µg/kg respectively for AFB1, AFB2 and AFG1. Total aflatoxin levels in white maize flours were higher than those in yellow maize flours with average levels of 26.61 µg/kg and 18.20 µg/kg respectively.

3.1.2. Household Flours

The results obtained for the samples taken from households are presented in **Table 3**. They show that in general, aflatoxins are more present in yellow maize than in white maize. Similarly, the total aflatoxin contents of yellow maize are higher than those of white maize with respective average contents of 29.34 µg/kg and 17.04 µg/kg respectively. For yellow maize flour, the average levels were 6.46 µg/kg, 7.29 µg/kg and 24.73 µg/kg respectively for AFB1, AFB2 and AFG1. For this type of flour, aflatoxin G2 was only recorded in one sample of white maize

Table 2. Aflatoxins levels in markets flours.

Types of maize flours	Samples	Level of aflatoxins (μg/kg)				
		AFB1	AFB2	AFG1	AFG2	AFT
White	MsW1	<Lod	4.30	<Lod	<Lod	4.30
	MsW2	<Lod	<Lod	<Lod	<Lod	<Lod
	MsW3	2.51	<Lod	14.01	<Lod	16.52
	MsW4	13.98	8.06	41.90	<Lod	63.94
	MsW5	5.34	4.41	11.94	<Lod	21.69
Yellow	MsY1	<Lod	<Lod	<Lod	<Lod	<Lod
	MsY2	2.88	<Lod	<Lod	<Lod	2.88
	MsY3	2.42	<Lod	14.00	<Lod	16.42
	MsY4	17.69	8.59	<Lod	<Lod	26.28
	MsY5	1.57	12.13	13.52	<Lod	27.22

Lod: Limit of detection.

Table 3. Aflatoxins levels in household flours.

Types of maize flours	Samples	Level of aflatoxins (μg/kg)				
		AFB1	AFB2	AFG1	AFG2	AFT
White	HsW1	<Lod	<Lod	<Lod	35.68	35.68
	HsW2	<Lod	<Lod	<Lod	<Lod	<Lod
	HsW3	<Lod	7.39	6.94	<Lod	14.33
	HsW4	<Lod	<Lod	<Lod	<Lod	<Lod
	HsW5	1.10	<Lod	<Lod	<Lod	1.10
Yellow	HsY1	18.38	9.01	30.82	<Lod	58.21
	HsY2	1.70	<Lod	6.29	<Lod	7.99
	HsY3	3.24	8.01	12.04	<Lod	23.29
	HsY4	<Lod	<Lod	49.76	<Lod	49.76
	HsY5	2.58	4.85	<Lod	<Lod	7.43

Lod: Limit of detection.

flour with a content of 35.68 μg/kg.

3.1.3. Supermarket Flours

The results obtained for the samples taken in Supermarket are presented in Table 4. These results show that aflatoxins are less present in the supermarket samples than in other two cases. Only one yellow maize flour sample contains AFB2 with a level of 4.08 μg/kg. For white maize flours, the average levels were 11.68 μg/kg, 7.02 μg/kg, 32.22 μg/kg and 26.45 μg/kg respectively for AFB1, AFB2, AFG1, and AFT.

For all 28 samples, the aflatoxin levels are highly variable. They ranged from

Table 4. Aflatoxins levels in supermarket flours.

Types of maize flours	Samples	Level of aflatoxins (µg/kg)				
		AFB1	AFB2	AFG1	AFG2	AFT
White	SsW1	0.89	<Lod	<Lod	<Lod	0.89
	SsW2	7.44	6.33	47.69	<Lod	61.46
	SsW3	1.71	<Lod	<Lod	<Lod	1.71
	SsW4	<Lod	3.92	<Lod	<Lod	3.92
	SsW5	36.69	10.81	16.75	<Lod	64.25
Yellow	SsY1	<Lod	<Lod	<Lod	<Lod	<Lod
	SsY2	<Lod	4.08	<Lod	<Lod	4.08
	SsY3	<Lod	<Lod	<Lod	<Lod	<Lod

Lod: Limit of detection.

undetected to 36.69 µg/kg and from undetected to 64.25 µg/kg respectively for AFB1 and AFT. These aflatoxins levels are similar to that of Bamba *et al.* [4] with average AFB1 contents of 0.79 ± 0.04 µg/kg to 20.92 ± 4.63 µg/kg in maize samples from 5 regions of Côte d'Ivoire. The AFB1 contents obtained during this study are higher than those revealed during a study carried out in Côte d'Ivoire on samples of maize flour with levels ranging from 0.12 µg/kg to 3.18 µg/kg [9]. They are also superior to that of Maskito *et al.* [6] who obtained a maximum AFB1 level of 15.62 µg/kg in maize flours in Kenya.

Contrariwise, higher average levels of AFB1 (108 µg/kg) with ranges of 5.7 to 309 µg/kg were found in maize flour samples from markets in Abidjan [18]. Similarly, AFB1 levels up to 1081 µg/kg were reported in maize samples [19].

For AFT, the levels recorded during this this study were similar to those of Bamba *et al.* [4] recorder in samples, ranging from 2.63 ± 2.35 µg/kg to 60.78 ± 30.24 µg/kg from five regions in Côte d'Ivoire. In contrast, high level of AFT were revealed by Kouadio *et al.* [18] which obtained a mean of 129 µg/kg with ranges of 4.5 to 330 in samples from Côte d'Ivoire. However, Manizan *et al.* [7] detected AFB2, and AFG1 at lower levels in maize flour samples (8 µg/kg for both AFB2 and AFG1) compared to the rates recorded during this study. The same authors detected 6 µg/kg for AFG2 in the same samples.

This study shows that in general, aflatoxin levels are lower in samples from supermarkets than in samples from markets and households. However, the statistical analysis shows that there is no significant difference between the AFB1 and AFT contents of flours from the three origins ($p = 0.726$ and $p = 0.966$ respectively). The low level of aflatoxins in supermarket samples can be explained by the fact that supermarkets source their supplies from particular producers who better respect GHP and GMP (Good Manufacturing Practices).

For the household samples, the aflatoxin level of yellow maize flours is higher than those of white maize flours. however, the analysis of variance shows that there is no significant difference between the aflatoxin contents of the two types of maize flours in the case of household samples (p = 0.168). According to some producers, yellow maize flour is often produced without ridding the grain of the bran. This could explain the higher levels of aflatoxins in this type of flour. Moreover, according to Diarra *et al.* [20], yellow maize is most often intended for animal nutrition, so, its conservation is not always done according to the same requirements as that of white maize. This could also justify the high levels of aflatoxins in yellow maize flours.

3.2. Prevalence of Aflatoxins in Flours

This study shows that the different types of aflatoxins (B1, B2, G1, G2 and AFT) are present in most samples. Total aflatoxins show the highest prevalence. Aflatoxins B are generally more common than aflatoxins G. The study also shows that supermarket samples have relatively lower contamination rates than household samples. Market samples show the highest contamination rates (**Table 5**).

Overall, for all the samples, the prevalence is 57.14% (16/28) for aflatoxin B1, 46.43% (13/28) for aflatoxin B2, 42.86% (12/28) for aflatoxin G1, 4.6% (1/28) for aflatoxin G1 and 78.57% (22/28) for total aflatoxins. Some studies show lowest prevalence compared to those recorded during this study. So, in study performed in Kenya on maize floor, it is noticed that the percentage of positive samples for aflatoxin B2, G1 and G2 were 7%, 33% and 13%, respectively [6]. According to the same study, the highest contamination was with aflatoxin B1 contaminating 40% of the samples analyzed. In contrast, high contaminations of aflatoxins were recorded in other studies. So, in recent study, AFB1 was recovered in 96%, AFB2 in 67%, AFG1 in 57% and AFG2 in 24% of maize samples [21].

For total aflatoxins, the low prevalence rate compared to those of this study was recorded in some studies on maize flours. Thus, 16.6% of contaminated samples was recorder in South Africa [22]. Similarly, 41.6% of contaminated samples was recorder in Nigeria [23].

3.3. Conformity of Samples

The levels of total aflatoxins and Aflatoxin B1 in foods are regulated. According to EC (European Community) Regulation No 1881/2006, the study shows that the compliance rates of the samples vary according to the origin and type of maize (**Table 6**). It also shows that non-compliance rates are generally lower in supermarket samples and higher in market samples.

In general, 78.57% of the samples showed contamination for at least one of the types of studied aflatoxin. For all the samples, 42.86% showed compliant AFT levels according to to EC Regulation [24] (less than 4 μg/kg). For AFB1, about 60.71% of the samples showed levels below 2 μg/kg. These samples are therefore of satisfactory quality, according to EC Regulation [24]. The results obtained by other authors confirm that the compliance rates of maize flour with respect to

Table 5. Contamination rate of samples.

	Number of contaminated samples and prevalence (%)		
	Market sample	Household sample	Supermarket sample
AFB1	07/10 (70%)	05/10 (50%)	04/08 (50%)
AFB2	05/10 (50%)	04/10 (40%)	04/08 (50%)
AFG1	05/10 (50%)	05/10 (50%)	02/08 (25%)
AFG2	00/10 (00%)	01/10 (10%)	00/08 (00%)
AFT	08/10 (80%)	08/10 (80%)	06/08 (75%)

Table 6. Samples compliance rate.

Types of samples	(%) of compliant samples			
	White maize flours		Yellow maize flours	
	AFB1	AFT	AFB1	AFT
Market	100	20	40	40
Household	100	60	40	00
Supermarket	60	60	100	80

AFB1 and AFT vary greatly from one study to another. So, According to Matsiko *et al.* [6], for aflatoxin B1, 13% of samples contained the levels of the aflatoxin, which were higher than Codex Alimentarius tolerable limit. Similarly, contamination levels higher than the EC limit for AFB1 were found in 61% of the contaminated maize samples, and for AFT in 53% of the same samples [7]. According to DE MARINIS *et al.* [25], contamination rates higher than the limit ranging from 25% to 100% were measured for AFT in divers' varieties of maize from Haiti.

This study shows that maize flours can constitute a danger for consumers with regard to the levels of contamination and consumption of this food product. Thus, it is essential to train those involved in maize production on good practices related to production, processing and conservation.

4. Conclusion

This study was conducted to evaluate the toxicological quality relating to the aflatoxin content of maize flour produced and sold in municipality of Ouagadougou. The analysis of the twenty-eight samples of maize flours revealed that the majority of these flours were contaminated with the different types of aflatoxins. The proportions of contaminated samples are variable, relatively high for AFB1 and low for AFG2. The aflatoxin contents of the samples are also very heterogeneous. Similarly, most of the samples show non-compliant AFB1 and AFT levels according to EC regulation.

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Conflicts of Interest

The authors declare that there is no conflict of interest related to this article.

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