Evaluation of the Relationship between the Quality Parameters of Stocked Maize Grains (Zea mays L.) in Polypropylene Bags Containing Leaves of *Lippia multiflora* (Verbanaceae) and *Hyptis suaveolens* (Lamiaceae)

Pierre Ezoua[1], Godi Henri Marius BIEGO[1, 2], Adama Coulibaly[3], Yves Nyamien[4], Ysidor N'guessan Konan[3], Daouda Sidibe[1]

[1]Laboratory of Biochemistry and Food Science, Training and Research Unit of Biosciences, Felix HOUPHOUET-BOIGNY University of Abidjan, 22 BP 582 Abidjan 22, Cote d'Ivoire

[2]Department of Public Health, Hydrology and Toxicology, Training and Research Unit of Pharmacological and Biological Sciences, Felix HOUPHOUET-BOIGNY University, BP 34 Abidjan, Cote d'Ivoire

[3]Training and Research Unit of Biological Sciences, Peleforo Gon COULIBALY University, BP 1328 Korhogo-Côte d'Ivoire

[4]Institute of Agropastoral Management, Peleforo Gon COULIBALY University, BP 1328 Korhogo-Côte d'Ivoire

Abstract: ***The aim of this study is to evaluate the existing relationships between quality parameters of maize grains stored for 9 months in polypropylene bags containing leaves of Lippia multiflora and Hyptis suaveolens. It was carried out in villages of Timbé and Soko respectively in departments of Katiola (Hambol region, Center-North) and Bondoukou (Gontougo region, Northeast) of Côte d'Ivoire. The mass losses and damages were determined by methods of Harris, Lindblad and Boxall. While moisture, aflatoxins and ochratoxin A were determined according to AOAC and European Commission regulation standard methods. The moisture content, weight loss and damages of maize grains was similar evolution to that of aflatoxin B1, total aflatoxins and ochratoxin A regardless of the study site and the grains treatment. However, this increase is faster in the control groups than in the lots containing the biopesticide leaves. For control batches, the variations or amplitude are between 111.23 µg/kg et 542.85 µg/kg for the mycotoxins (aflatoxins and ochratoxin A) and between 3.02% and 46.32% for merchantability parameters (moisture content, mass loss and grains damages), regardless the site. As for the lots containing the leaves, they have variations or amplitudes varying between 2.06% and 27.69% for the merchantability parameters and ranging from 4.34 µg/kg and 107.12 µg/kg for the mycotoxins whatever the site. Therefore the correlation coefficients determined between the merchantability and sanitary quality parameters are all greater than 0.684 regardless of the site and type of maize grains treatment. Thus, a particular attention, from the producers, must be focused on the initial quality, the conditions and the storage environment of maize grains in order to optimize the biopesticide effect of the leaves for a long-term storage.***

Keywords: correlation coefficient, quality, maize grains, polypropylene bag, biopesticide

1. Introduction

Food shortages are due not only to inadequate production, but also to post-harvest losses. Indeed post-harvest conservation, particularly of cereals, is currently of concern to producers and agricultural services in most African countries. The losses are very variable according to regions or even countries. Studies have shown that losses due to pests during storage can reach 30% of production [1]-[3]. Several deterioration agents are responsible for these losses, particularly insects (44%), rodents (30%) and fungi (26%), as described by Huignard [4] and Foua-Bi [5]. This damage not only reduces the weight and germinative power of grains but also degrades their nutritive, merchant and sanitary qualities [6], [7]. Maize grains, which are widely consumed throughout the world, do not escape the rule as demonstrated by several scientific works [8], [9].

Maize is the most widely used basic food crop in sub-Saharan Africa. In addition, more than 300 million people in sub-Saharan Africa depend on maize as source of food and subsistence [10]-[11]. Of 22 countries in the world where maize accounts for highest percentage of calories in national diet, 16 are in Africa notably Côte d'Ivoire [12]. Maize is a well-established crop in Côte d'Ivoire [13]. In 2014, annual production was estimated at 680000 tonnes [11]. It is consumed in several forms by both humans and animals. Indeed, fresh maize cobs can be boiled (kaba-bélégué) or simply braised. Maize flour is prepared as cake cooked, boiled or in a more compact form (kabatoh). The fermentation of maize grains produces alcohol that is used in preparation of beverages (tchapalo, beer, whiskey). Whole plant can also be consumed by livestock as forage (fresh or dry) or ensilage [14]. However, various constraints have also been identified in this sector, particularly post-harvest losses.

Faced with these post-harvest losses, different control methods have been developed. These include chemical control, biological control, use of plant biocidal substances, physical methods and varietal resistance [3], [15]. According to Isman [16] and PAN Africa [17], synthetic chemical insecticides are most widely used. The abuse of pesticides to control insects in stored foodstuffs has often resulted in presence of toxic residues on treated products and leading to appearance of resistant insects [18]. In developing countries, these disadvantages are added to economic constraints related to the cost and supply of active ingredients [19]. It is important in the face of these problems to look for other alternative methods of control available to farmers, which are cheaper, respectful of environment and guarantee the health of consumers. Therefore, this study was initiated to evaluate the existing relationships between quality parameters of maize grains stored in polypropylene bags containing leaves of two plants with biopesticide properties.

2. Material and Methods

2.1 Site description

The study was conducted in the villages of Timbe and Soko respectively located in the departments of Katiola (Hambol region) (8°10'N 5°40'W) and Bondoukou (Gontougou region) (8°30'N 3°20'W) in the Central North and North East of Cote d'Ivoire. The both localities have a humid tropical climate with four (4) seasons, including two (2) rainy seasons from March to July and October to November. These are interspersed with two (2) dry seasons ranging from December to February and August to September. The annual rainfall ranging between 1100 and 1200 mm in Katiola and between 800 and 1400 mm in Bondoukou. The average temperatures recorded in these areas vary between 26.5°C and 33.7°C in Katiola and between 24°C and 29°C in Bondoukou. The recorded average of humidity range between 60%-70% for the both region [20]-[24].

2.2 Plant material collection and processing

The biological material consisted of maize grains collected in January 2014 and leaves of plant species *Lippia multiflora* (or savannah tea) and *Hyptis suaveolens* collected for their biopesticides properties. These plants are perennials and fragrant shrubs that develop spontaneously from the central to the Northern parts of the country due to the climatic environment [25], [26]. After harvest, maize was sun-dried and leaves of *L. multiflora* and *H. suaveolens* were drying at an average temperature kept away from direct sun exposure.

2.3 Experiments implementation

The implementation of the study was conducted from January to September 2014, with the participation of 2 Informal Groups (IG) of farmers. They are the IG "Sounougou" of Soko in Bondoukou and the IG "Lagnimin" of Timbe in Katiola. These farmers accustomed to preserve their maize grain in polypropylene bags in a corner of the house. Method tested in this study, consisted in adding of phytopesticides (5% w/w) in the polypropylene bags containing maize grains and storing on pallets in warehouses for 9 months. The steps of adding phytopesticides (*Lippia multiflora* and *Hyptis suaveolens*) and deposit bags on pallets constitute the principal modifications made to the method of conservation practiced by these farmers. Leaves of *L. multiflora* and *H. suaveolens* were chopped and the filling of the bags was performed by alternately as maize grains strata and phytopesticides. Thus, polypropylene bags containing 50 kg of maize grain and 5% w/w of *H. suaveolens* (A) or *L. multiflora* (B) or in mixture (A+B) were stored as described below :

- Treatment 1: 50 kg of maize grain + 2.5 kg of leaves of *H. suaveolens* (A) ;
- Treatment 2: 50 kg of maize grain + 2.5 kg of leaves of *L. multiflora* (B) ;
- Treatment 3: 50 kg of maize grain + 1.25 kg of leaves of *L. multiflora* + 1.25 kg of leaves of *H. suaveolens* (A+B) ;
- Treatment 4: control (50 kg of maize grain alone).

The treatments were laid out in a randomized complete block design in each zone of study, and each treatment was replicated 3 times.

2.4 Determination of merchantability parameters

The moisture content, damage and weight loss were determined by the AOAC method [27], the counting and weighing methods of Harris and Lindblad [28] and Boxall [29] respectively, as reported by Ezoua et *al.*[22], [23].

2.5 Sanitary parameters analysis

Aflatoxins and ochratoxin A were extracted and assayed according respectively to AOAC [30] and European Commission regulation [31] as described by Ezoua et *al.*[23], [24].

2.6 Statistical analysis

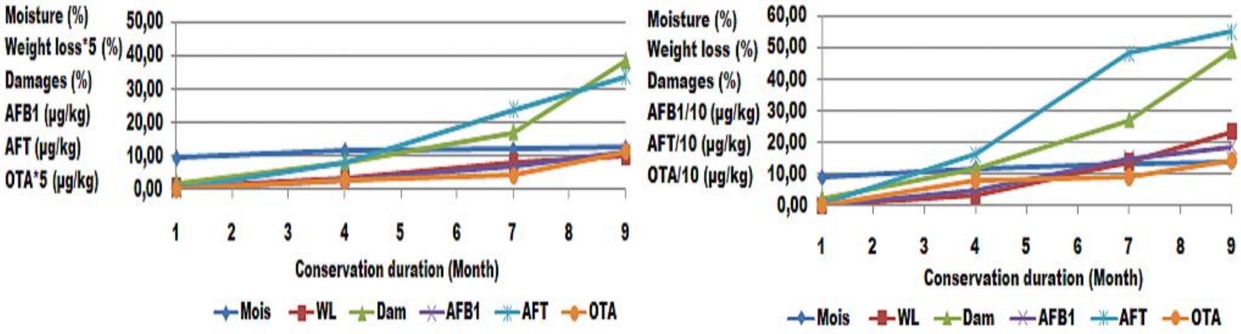
All analyses were performed in triplicate and the full data were statistically treated using SPSS software (version 20.0). The evolution of the parameters of the grain merchantability and sanitary was evaluated through graphics made from Excel 2007 software. The correlation between the parameters was evaluated using Excel 2007 software and the SPSS version 20.0 at 5% risk.

3. Results and discussion

3.1. Results

3.1.1. Evolution of merchantability and sanitary parameters of grains in the control batches

The moisture content, weight loss and damages of maize grains in the control batches was similar evolution to that of aflatoxin B1, total aflatoxins and ochratoxin A regardless of the study site. This ascending rate is greater with mycotoxins than the merchantability parameters regardless of the study site. In the Katiola area, the variations or amplitude are 112.06 µg/kg, 335.32 µg/kg, and 111.23 µg/kg respectively, for aflatoxin B1, total aflatoxins and ochratoxin A. However they are respectively 3.02%, 9.34%, and 36.35% for moisture content, weight loss and grains damages. For Bondoukou area, the variations are 4.89%, 23.07% and 46.32% respectively for moisture content, weight loss and grains damages. However, they are respectively 185.24 µg/kg, 542.85 µg/kg and 140.24 µg/kg, for aflatoxin B1, total aflatoxins and ochratoxin A (Figure 1).



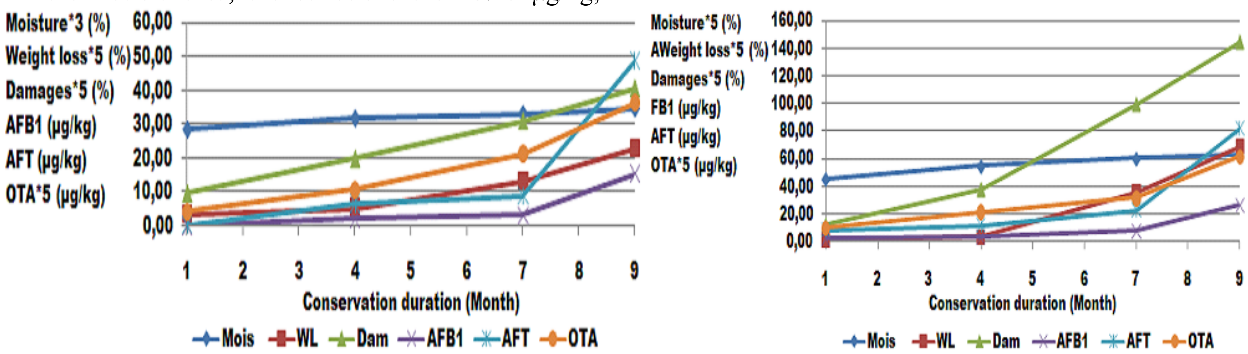
a b

Moist: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Figure 1 : Evolution of merchantability and sanitary parameters of maize grains during storage for control batches at Katiola (a) and Bondoukou (b)

3.1.2. Evolution of merchantability and sanitary parameters of grains stored with leaves A

The moisture content, weight loss and damages of maize grains stored with leaves A was similar evolution to that of aflatoxin B1, total aflatoxins and ochratoxin A regardless of the study site. This ascending rate is greater with mycotoxins than the merchantability parameters regardless of the study site, except aflatoxin B1 and ochratoxin A in Bondoukou area. In the Katiola area, the variations are 15.13 µg/kg, 48.02 µg/kg and 6.38 µg/kg respectively, for aflatoxin B1, total aflatoxins and ochratoxin A. However they are respectively 2.06%, 3.85%, and 6.16% for moisture content, weight loss and grains damages. For Bondoukou area, the variations are 3.50%, 13.47% and 26.54% respectively for moisture content, weight loss and grains damages. However, they are respectively 23.71 µg/kg, 73.22 µg/kg and 10.29 µg/kg, for aflatoxin B1, total aflatoxins and ochratoxin A (Figure 2).



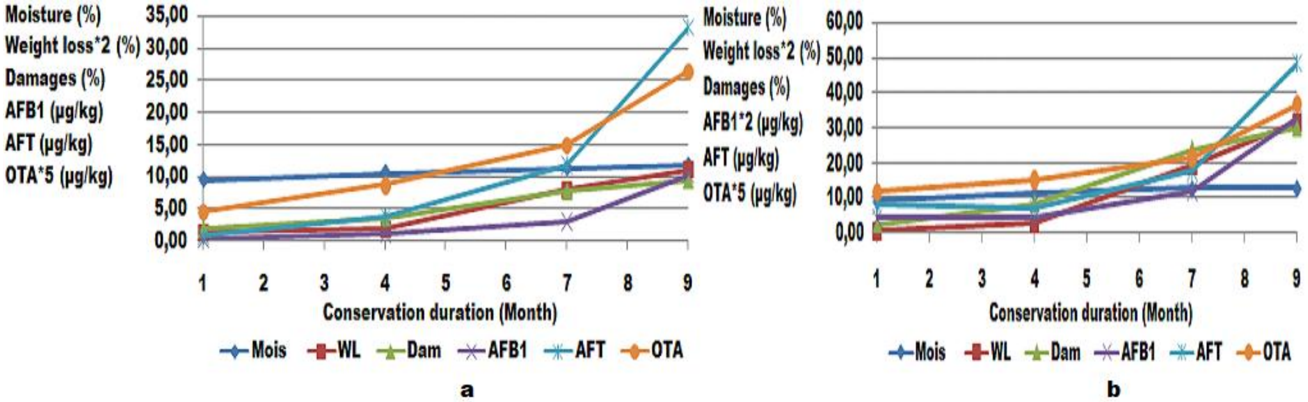
a b

Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Figure 2: Evolution of merchantability and sanitary parameters of maize grains during storage with the leaves A at Katiola (a) and Bondoukou (b)

3.1.3. Evolution of merchantability and sanitary parameters of grains stored with leaves B

Figure 3 shows that merchantability and sanitary parameters of maize grains increases during storage with leaves B regardless of the study site. The low variation value is obtained with the moisture content for merchantability parameters and the ochratoxin A for the mycotoxins regardless of the study site. In the Katiola area, the variations are 10.01 µg/kg, 32.18 µg/kg and 4.34 µg/kg respectively, for aflatoxin B1, total aflatoxins and ochratoxin A. However they are respectively 2.25%, 4.76%, and 7.47% for moisture content, weight loss and grains damages. For Bondoukou area, the variations are 3.68%, 15.49% and 27.69% respectively for moisture content, weight loss and grains damages. However, they are respectively 14.11 µg/kg, 40.21 µg/kg and 4.93 µg/kg, for aflatoxin B1, total aflatoxins and ochratoxin A (Figure 3).

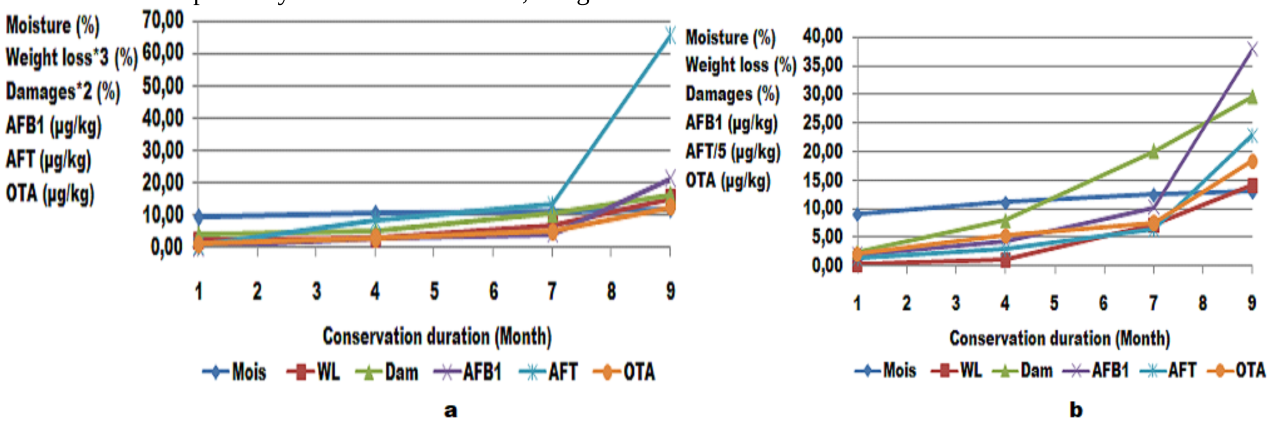


Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Figure 3: Evolution of merchantability and sanitary parameters of maize grains during storage with the leaves B at Katiola (a) and Bondoukou (b)

3.1.4. Evolution of merchantability and sanitary parameters of grains stored with leaves A+B

Figure 4 shows that the merchantability and sanitary parameters have an upward trend regardless of the site. However, the variations are more important with mycotoxins than the merchantability parameters except for ochratoxin A at Bondoukou area. This mycotoxin has a lower variation than damages. The variations obtained in Katiola are 2.35%, 4.31% and 6.18% respectively for moisture content, weight loss and grains damages and 21.14 µg/kg, 64.94 µg/kg and 11.15 µg/kg respectively for aflatoxin B1, total aflatoxins and ochratoxin A. For the Bondoukou site, the variations are 3.98%, 13.81%, 27.17%, 35.82 µg/kg, 107.12 µg/kg and 16.18 µg/kg respectively for moisture content, weight loss, grains damages, aflatoxin B1, total aflatoxins and ochratoxin A.



Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Figure 4: Evolution of merchantability and sanitary parameters of maize grains during storage with the leaves A+B at Katiola (a) and Bondoukou (b)

3.1.5. Coefficient of correlation between quality parameters according to the type of maize grains treatment

The correlation coefficients determined between the merchantability and sanitary quality parameters are all greater than 0.684 regardless of the site and type of maize grains treatment. For control batches, these coefficients are 0.822-0.996 and 0.892-0.973 respectively for Katiola and Bondoukou (Table 1). Among the lots stored with leaves A, the coefficients at Katiola and Bondoukou are 0.790-0.995 and 0.723-0.967 respectively (Table 2). The coefficients obtained with lots stored with leaves B are 0.808-0.958 for Katiola and 0.684-0.965 for Bondoukou (Table 3). Table 4 presents the coefficients obtained with the batches preserved with leaves A + B and these coefficients are 0.874-0.990 for Katiola and 0.753-0.965 for Bondoukou.

Table 1: Coefficient of Correlation between the Quality Parameters of the maize grains in the Control batches

Katiola						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,908	1,000				
Dam	0,807	0,929	1,000			
AFB1	**0,875**	**0,987**	**0,976**	1,000		
AFT	**0,883**	**0,996**	**0,954**	0,997	1,000	
OTA	**0,822**	**0,901**	**0,992**	0,954	0,927	1,000
Bondoukou						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,881	1,000				
Dam	0,884	0,994	1,000			
AFB1	**0,954**	**0,973**	**0,959**	1,000		
AFT	**0,961**	**0,957**	**0,940**	0,998	1,000	
OTA	**0,947**	**0,892**	**0,925**	0,906	0,894	1,000

Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Table 2: Coefficient of Correlation between the Quality Parameters of the maize grains stored with the leaves A

Katiola						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,887	1,000				
Dam	0,974	0,963	1,000			
AFB1	**0,806**	**0,943**	**0,867**	1,000		
AFT	**0,790**	**0,932**	**0,852**	1,000	1,000	
OTA	**0,927**	**0,995**	**0,981**	0,941	0,929	1,000
Bondoukou						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,849	1,000				
Dam	0,932	0,982	1,000			
AFB1	**0,743**	**0,952**	**0,903**	1,000		
AFT	**0,723**	**0,939**	**0,885**	0,999	1,000	
OTA	**0,872**	**0,967**	**0,960**	0,975	0,969	1,000

Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Table 3: Coefficient of Correlation between the Quality Parameters of the maize grains stored with the leaves B

Katiola						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,902	1,000				
Dam	0,963	0,984	1,000			
AFB1	**0,808**	**0,900**	**0,868**	1,000		
AFT	**0,838**	**0,929**	**0,900**	0,997	1,000	
OTA	**0,911**	**0,958**	**0,951**	0,977	0,988	1,000
Bondoukou						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,864	1,000				
Dam	0,940	0,982	1,000			
AFB1	**0,707**	**0,942**	**0,872**	1,000		
AFT	**0,684**	**0,932**	**0,856**	0,999	1,000	
OTA	**0,801**	**0,965**	**0,922**	0,989	0,984	1,000

Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

Table 4: Coefficient of Correlation between the Quality Parameters of the maize grains stored with the leaves A + B

Katiola						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,906	1,000				
Dam	0,943	0,984	1,000			
AFB1	**0,876**	**0,971**	**0,923**	1,000		
AFT	**0,874**	**0,972**	**0,924**	1,000	1,000	
OTA	**0,929**	**0,990**	**0,968**	0,989	0,989	1,000
Bondoukou						
	Mois	**WL**	**Dam**	**AFB1**	**AFT**	**OTA**
Mois	1,000					
WL	0,866	1,000				
Dam	0,941	0,983	1,000			
AFB1	**0,753**	**0,957**	**0,906**	1,000		
AFT	**0,754**	**0,956**	**0,906**	1,000	1,000	
OTA	**0,830**	**0,965**	**0,938**	0,990	0,991	1,000

Mois: moisture content; **WL**: weight loss; **Dam**: damages; **AFB1**: aflatoxin B1; **AFT**: total aflatoxins; **OTA**: ochratoxin A

3.2. Discussion

The leaves used in this study had no significant effect on the evolution of merchantability parameters (moisture, weight loss and grain damage) and sanitary quality (aflatoxin B1, total aflatoxins and ochratoxin A). This situation is independent of the study area and the type of maize grain treatment. Indeed, the upward evolution of these parameters during storage has not varied regardless of the site, the sheets used and the storage period. However, this increase is faster in the control groups than in the lots containing the biopesticide leaves and this is visible with the amplitudes of the curves regardless of the quality parameter.

Contamination of maize grains by mycotoxins (aflatoxins and ochratoxin A) evolves more rapidly than insect action or moisture content. Indeed, a slight evolution in the moisture content or the action of insects on the grains, during storage, causes a sharp change in the level of contamination with aflatoxin B1, total aflatoxins or ochratoxin A. This situation is more accentuated in control batches than lots stocked with the leaves of biopesticide. This evolution is approximately 9 to 12 times more important for mycotoxins (aflotoxin B1, total aflatoxin and ochratoxin A) than the moisture or insect action in control batches and 2 to 11 fold higher in the lots containing leaves. This relationship between the parameters of the merchantability of maize grains during storage and the occurrence of aflatoxin B1, total aflatoxins and ochratoxin A is confirmed by a significant and positive correlation. However, the leaves do not have a real effect on the meaning of this relationship since the correlation coefficients r are between 0.822 and 0.996 for the control batches and between 0.723 and 0.995 for the lots containing leaves. This would mean that rehumidification of maize grains during storage with leaves of *H. suaveolens*, *L. multiflora* or a mixture of the 2 would lead to an increase in the level of contamination with aflatoxin B1, total aflatoxins and ochratoxin A. These results corroborate those of Niamketchi [32], who showed a positive correlation between water activity (Aw) and levels of aflatoxin B1 contamination, total aflatoxins and ochratoxin A of maize grains. These grains were stored in granaries containing leaves of *H. suaveolens* or *L. multiflora*. This author found correlation coefficients r between 0.60 and 0.62 between water activity and level of grains contamination in aflatoxin B1, total aflatoxins and ochratoxin A.

4. Conclusion

The leaves of *L. multiflora* and *H. suaveolens* possess biopesticidal properties which preserve the quality of maize grains during storage in polypropylene bags. However, the use of *L. multiflora* leaves or *H. suaveolens* has no significant influence on the positive correlation between the merchantability parameters of grains and those of sanitary quality during storage. Thus, a particular attention, from the producers, must be focused on the initial quality, the conditions and the storage environment of maize grains in order to optimize the biopesticide effect of the leaves for a long-term storage.

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