Assessment of Cowpea (*vigna unguiculata* (l), walp) Storage Technique and some Stocks Sanitary Quality in Center North Region of Burkina Faso.

ABSTRACT

Cowpea plays an important role in food and nutritional security. Cowpea stock are subject to biotic and abiotic attack resulted stock lost that affected food security. Few research are doing on conservation techniques and stock sanitary quality. The objective of this work is to study the cowpea storage techniques and some stock sanitary quality according to producers and with laboratory analysis. A survey was conducted with 174 cowpea producers on storage techniques and 17 samples of cowpea were collected in stocks to determine aflatoxin B1 level and grain quality parameter according to official method. It was found that cowpea is preserved in the form of grains (98.28%), the house is the main storage structure (89.66%), the double-bottom bag is the most commonly used packaging material (57.71%), chemical substances are the most commonly used for preservation (52.19%), and pallets are generally used to furnish the interior of the storage structure (73.56%). Insects and rodents (43.43% and 42.7% respectively) were the most encountered stock enemies and moisture (44.65%) the main abiotic spoilage factor. An AFTB1 contamination rate of 94% was found in the cowpea stocks sampled, 52.63% of which had levels above the maximum limit set by the European Commission for raw materials (2 µg/kg). Correlation analysis showed a relationship between AFTB1 levels, moisture, pH, moldy kernels and kernel acidity. This study revealed that chemical product are more use to conserve cowpea and 94% of stocks sample were contaminated by aflatoxin B1 while half of them are levels above maximum limit.

Keywords: cowpea, conservation, sanitary quality, Burkina Faso.

- **INTRODUCTION**

Cowpea (Vigna unguiculata (L), Walp), once considered a food crop, is increasingly becoming both a food and cash crop (Gonçalves & Santo, 2016; Linguya, Moraa, Wangai, & Chao, 2015). It is one of the main food legumes produced worldwide (Zakari, Baoua, Amadou, Tamò, & Pittendrigh, 2019). In 2020/2021, cowpea is ranked first among legumes produced in Burkina Faso (EPA, 2021). Cowpea is one of the main sources of nutrients for populations in West African countries (Gonçalves & Santo, 2016; Kirigia, Winkelmann, Kasili, & Mibus, 2018; Linguya et al., 2015). It plays an important role in achieving food security through its availability during the lean season (Sissoko, VeroniqueTheriault, & Smale, 2021). Thanks to its high protein content (25%), cowpea can be used as a protein supplement to more expensive animal proteins. Several studies have been carried out on cowpeas, including varietal selection, which has led to the development of high-yielding varieties, varieties resistant to drought and cowpea bruchids, and short-cycle varieties (60 days) (Murdock, Seck, Ntoukam, Kitch, & Shade, 2003). This work has made cowpea one of the most widely produced and consumed legumes in West Africa, and in Burkina Faso in particular (EPA, 2021). The problems currently facing the agricultural sector, particularly the cowpea sector, are pests and the risks associated with aflatoxin contamination (Keller et al., 2022). For the cowpea sector, these problems start in the field and become more acute during storage. Given its seasonal nature, cowpeas must be stored and preserved for distribution and consumption throughout the rest of the year (Murdock et al., 2003). Studies have shown that during storage, cowpeas are subject to biotic and abiotic spoilage factors that can render them unfit for human and animal consumption, resulting in losses of between 17.3% and

90% (FAO, 2018; FAO, PAM, & FIDA, 2019; Ngamo & Hance, 2007; Smith et al., 2016; Sugri, Mutari, Owusu, & Bidzakin, 2021; Tai, Chang, Liu, & Xing, 2020). The biotic factors that spoil cowpea grains during storage are mainly insects, rodents and molds. Authors have shown that rodents and insects consume grains, perforate them and pollute them (Mutiga et al., 2014). Perforated grains are no longer fit for human consumption (Sugri et al., 2021). Molds colonize grains either from the field or through the action of rodents and insects during storage (Gauthier, 2016). When conditions are favorable, these molds develop and produce toxins that affect the sanitary quality of cowpeas. Molds of the genera Aspergillus, penicillium, and Fusarium are fungi whose colonies are visible to the naked eye after 7 days of growth and are the main producers of the most toxic mycotoxins including aflatoxins, fumonisins, ochratoxin A (OTA), and deoxynivalenol (DON) (Dedi & Diomande, 2017; Gnonlonfin et al., 2013; Mostrom, 2016; Raiola, Tenore, Manyes, Meca, & Ritieni, 2015; Shephard, 2008; Udomkun et al., 2019). Aflatoxin contamination of crops also leads to huge economic losses in Africa, with export product rejections of 39% (Chilaka, Obidiegwu, Augusta Chinenye Chilaka, Atanda, & Mally, 2022). Abiotic spoilage factors include temperature, humidity, pH, etc., as well as poor pre-harvest and post-harvest hygiene; according to several authors, these factors favor mold growth and toxin production (Cruz, Hounhouigan, & Fleurat-Lessard, 2016; Keller et al., 2022). Studies sown that cowpea stored in hermetique triple layer bag with moisture inferior to 14% reduced aflatoxin contamination (Nganga, Mutungi, Imathiu, & Affognon, 2016). There is a synergy between biotic and abiotic parameters in aflatoxin contamination of stocks (Bradford et al., 2018; Tai et al., 2020). Studies have shown that temperature and relative humidity are climatic risk variables for aflatoxin contamination of stocks (Smith et al., 2016; Tai et al., 2020). Relative humidity and temperature variations influence stock humidity and the growth of mycotoxin-producing molds (Bradford et al., 2018). Among these toxins, group B aflatoxins are the most harmful to humans and animals, notably aflatoxin B1 (Hussein & Brasel, 2001; Lavkor & Var, 2017). Aflatoxins are responsible for several diseases including liver cancers, intoxications and stunted growth in children according to several studies (AFSSA, 2013; IARC, 2012, 2015; Kensler, Roebuck, Wogan, & Groopman, 2011; Misihairabgwi, Ezekiel, Sulyok, Shephard, & Krska, 2019; Wu, 2015). The impact of biotic and abiotic factors on cowpea quality may depend on preservation techniques. The aim of this work is to study the impact of biotic and abiotic factors on the sanitary quality of cowpeas through the study of preservation techniques and laboratory analyses.

- **MATERIALS AND METHODS**

- ***Study areas***

The study took place from October 2020 to January 2021 in three communes of the Centre Nord region of Burkina Faso: Boussouma, Korsimoro and Pissila. The study was carried out among producers of cereals and legumes, including cowpeas.

Table 1 : Summary table of the study area

Climate zone	town	villages
Sub-Sahelian zone 13°05'North 1°05' West	Boussouma	Boussouma, Zikiema
	Korsimoro	Taonsin, yimiougou
	Pissila	Lebda, Goema, Forgui

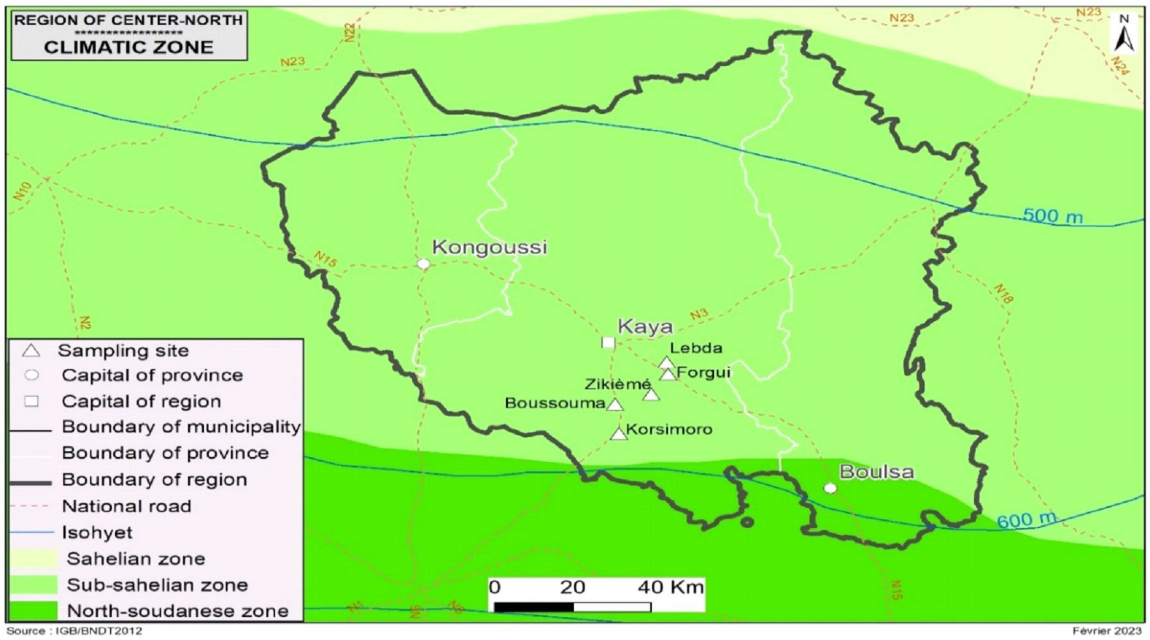


Figure 1 Map of study area

2.2. Type of study

This cross-sectional study enabled us to collect qualitative and quantitative data. It consisted in administering a questionnaire to producers on cowpea storage and conservation techniques. It is a household survey, with the head of household or his representative as respondent. The representative is chosen from among those who are familiar with the household's production and storage techniques.

- **Sampling**

Sampling is carried out by drawing lots among the growers; it is a systematic sampling which, after randomly drawing the first grower, goes directly to the next grower. The sample size is calculated using the proportion of growers (80%) as the probability of calculation, with a confidence interval of 95% and a margin of error of 5%. This gave us a minimum sample of 250 producers, following the method described by Dohoo et al. in 2009 (Dohoo, Martin, & Stryhn, 2009(Lwanga, 1991)). After a pre-analysis, a sample was taken from the cowpea stocks of seventeen producers randomly selected from among those surveyed. Samples were taken at three or four points, depending on the container containing the cowpea, or after homogenization for small containers; the sub-samples were put together to obtain the sample, which gave us seventeen (17) samples. The physico-chemical characteristics of the 17 samples were determined. The sample size for collecting data on cowpea preservation techniques was calculated using the formula given by Dohoo et al. in 2009.

Where n= sample size

Z= confidence interval

P= percentage of producers in the population

D= precision

- **Data collection**

Data were collected by administering a 70-question questionnaire to 174 cowpea growers in the three communes of the Centre Nord region of Burkina Faso. Once the questionnaire had been designed, it was presented to grower representatives to adapt it to the realities of the field. ODK software was installed on tablets and used for data collection. The questionnaire was administered to rural producers and provided information on the socio characteristics of the producer, such as age, sex, training received in preservation techniques, membership of a producers' association, crops produced and post-harvest preservation techniques, as well as stock deterioration factors. The respondent was the head of the household or his or her representative, who is a member with good knowledge of household production (Lwanga, 1991).

- **Physico-chemical characteristics**

  - ***Grain moisture***

Grain moisture is the loss of mass expressed as a percentage, experienced by the product under the specific conditions. The moisture content of the samples was determined according to the AOAC 925.10 method (AOAC, 1990). This method consists of oven drying at 105°C followed by weighing the residue. Five (5) grams (g) of cowpea flour were weighed in aluminum baskets previously washed, dried and tared. The whole was placed in a ventilated oven at 105°C during 24 h and cooled in the desiccator during 30 mn then weighed. The tests were done in doublet. The water content was calculated according to the following relation:

PE: Take for test (g); M0: empty mass of the pods (g); MF: final mass (pods + dry matter) after passage in the oven (g).

  - ***Determination of the weight of 1000 seeds***

The weight of 1000 seeds of cowpea samples was determined by the method of Cruz (Cruz et al., 2016). One hundred (100) seeds of each cowpea sample were counted in triplicate and then weighed on an analytical electronic balance type OHAUS (±0.0001). The mass obtained for each batch of 100 seeds made it possible to calculate its weight for 1000 seeds by applying the formula below

Mn =mn*1000/100

Mn= mass of 1000 seeds of each trial (n= 1, 2,3); mn= mass of 100 seeds of each trial (n= 1, 2,3)

The arithmetic mean of the masses of the three batches (M) is taken as the mass of 1000 seeds (TWG) in the sample (Cruz et al., 2016).

  - ***Infestation of seeds***

After homogenization, 100g of each sample was weighed and then manually the seeds with an insect entry hole (perforated seeds) were separated, the moldy ones as well as the broken or heavily damaged seeds. Each lot was weighed and the weight was noted according to NBF 01-100 (ABNORM, 2019). The results are given by the following formulas:

Perforation rate

Mouldy grain rate

Broken grain rate

The operation is repeated three times and the arithmetic mean of the percentages is determined for each parameter.

- ***Determination of pH and acidity***

Acidity and pH were determined according to the AOAC method 943.02 (AOAC, 1990). Five (5) g of ground sample was suspended in 25 ml of distilled water. After strong magnetic stirring, the pH was measured using a previously calibrated pH meter. For the determination of acidity, the solution was centrifuged at 5000 g for 5 min; the supernatant was collected and titrated with 0.1 M NaOH in the presence of phenolphthalein and the content calculated as percentage of citric acid.

- ***Determination of aflatoxin B1 in cowpea***

Immunological method ELISA (Enzyme-Linked Immunosorbent Assay) was used to determine AFTB1 in cowpea

- Principle: The indirect competition ELISA test was used for the analysis of these samples. In this method, the competition is between the labeled enzyme and the toxin present in the sample or in the standard (Dohoo et al., 2009).

- Procedure

- AFB1-BSA conjugate was prepared in Carbonate Coating Buffer at a concentration of 150ng/ml and 150µl of the solution was dispensed into each hole of the ELISA plate. The plate was then incubated at 37°C for at least 1 hour and washed three times with PBS-Tween. 150µl of 0.2% BSA prepared in PBS-Tween and incubated at 37°C for 1 hour is added to each hole of the plate and washed three times with PBS-Tween.

- Preparation of aflatoxin B1 standard solutions: Dilution was done with healthy cowpea seed extract and the concentration varied from 10ng to 0.09ng in a volume of 100 µl.

In a tube a suitable dilution of antiserum in PBS-Tween containing 0.2% BSA was prepared and 50 µl of this dilution of antiserum was added to each dilution of standard (100 µl) and to each hole containing the sample to be analyzed (100 µl). The plate was incubated for 1 hour at 37°C to facilitate the reaction between the toxin present in the samples with the antibody and then washed three times with PBS-Tween.

- Dilution of the anti-rabbit IgG obtained from the labelled rabbit with Alkaline Phosphate PBS-Tween containing 0.2% BSA was prepared and 150µl was dispensed into each hole of the plate. The platelet was then incubated for 1 hour at 37°C and washed three times with PBS- Tween. The substrate solution (p- Nitrophenyl Phosphate) prepared in diethanolamine buffer (10%, pH= 9.8) was added and the plate was again incubated at 37°C for 30 minutes. A curve is then plotted taking the Aflatoxin B1 concentrations on the x-axis and the optical density values on the y-axis.

- The concentration of Aflatoxin B1 is expressed by the following formula:

(Expressed in µg/kg)

A=concentration of AFB1 in diluted or concentrated sample extract (ng/ml); D=number of times diluted with buffer; E=volume of solvent used for extraction (ml); G=sample weight(g)

Data processing

The data processing was done by Excel 2013 software and the analyses by R v4.2.2 and Excel 2013 software. Excel was used to calculate the mean and the SD, Rcomander and RGUI were used to analyze the correlation.

- **RESULTS**

Figure 2 type of storage **figure** 3 Cowpea storage structures

Cowpea storage structures and type of storage (figures 4 and 5): cowpea is mainly stored in grain form (98.28%). The house is the most commonly used storage structure (89.66%).

Figure 4 internal layout of the storage structure **figure** 5 chemicals used for internal layout

The internal layout of the storage structure: this is a means of protecting stocks; this technique prevents insects that might crawl up from the ground to colonize stocks, notably termites, or to protect stocks from abiotic factors such as humidity. This technique involves either placing pallets on which the packaged cowpeas are stored, or sprinkling chemical or natural substances on them; these substances are either insecticides or insect repellents, or spreading a tarpaulin. Pallets are the most widely used for this purpose (73.56%) (Figure 4).

Chemicals used for internal layout : two chemicals are mainly used for the internal layout of the storage structure; their trade names are calthio, phostoxin and rambo. The chemical rambo is the most widely used with 66.67% of producers, followed by phostoxin with 33.33% of producers (Figure 5).

Figure 6 packaging equipment

Cowpea packaging equipment: before storage, cowpeas are packaged in containers such as bags, drums and cans. Packaging either isolates the product from its environment, protecting it from biotic and abiotic factors, or facilitates storage. The double-bottom bag is the most commonly used packaging material (57.71%), followed by the plastic bag (17.18%) and the drum (13.66%) (Figure 6).

Figure 7 Cowpea preservatives **figure** 8 chemical preservatives

Cowpea preservatives and Chemical preservatives use in cowpea : after packaging, protective substances are often added to the cowpea to preserve it. Both chemical and natural preservatives are generally used. Chemical preservatives are used the most by 52.19% of producers (figure 7).

The chemical preservatives used are phostoxin and calthio, with 53, 85% and 28.67% of producers respectively (figure 8).

Figure 9 Enemies of cowpea stocks **figure** 10 Abiotic factors affecting cowpeas

Enemies of cowpea stocks: insects, rodents and moulds were the main pests of cowpea stocks encountered, with 43.43%, 42.70% and 10.58% respectively (figure 10). Other enemies such as

air and animals were cited as pests of stocks.

Abiotic factors affecting cowpeas: during storage, cowpeas can be affected by abiotic factors. These factors especially favor the proliferation of molds and the possible production of their toxins on cowpeas. Moisture, lack of hygiene, the state of ripeness of the grains (immature grains) and late harvesting are the main abiotic factors identified (figure 11). According to growers, humidity and lack of hygiene are the major risk factors, with 44.65% and 16.51% respectively. These factors vary from one agro-climatic zone to another. Other factors such as the type of structure and packaging equipment, the presence of air in the product, animals and long storage times were also cited.

Figure 11 Cowpea storage life techniques

figure 12 Satisfaction with preservation

Cowpea storage life (figure 11): According to the producers, their storage techniques enable them to store cowpeas for 6 to 12 months for the majority (58.05%); less than 6 months (25.29%) and few producers manage to store their cowpeas for more than a year (16.67).

Satisfaction with preservation techniques (figure 12): 55.17% of growers are satisfied with their cowpea preservation techniques and 44.83% are not satisfied with their cowpea preservation techniques.

Figure 13 Diagram of cowpea storage

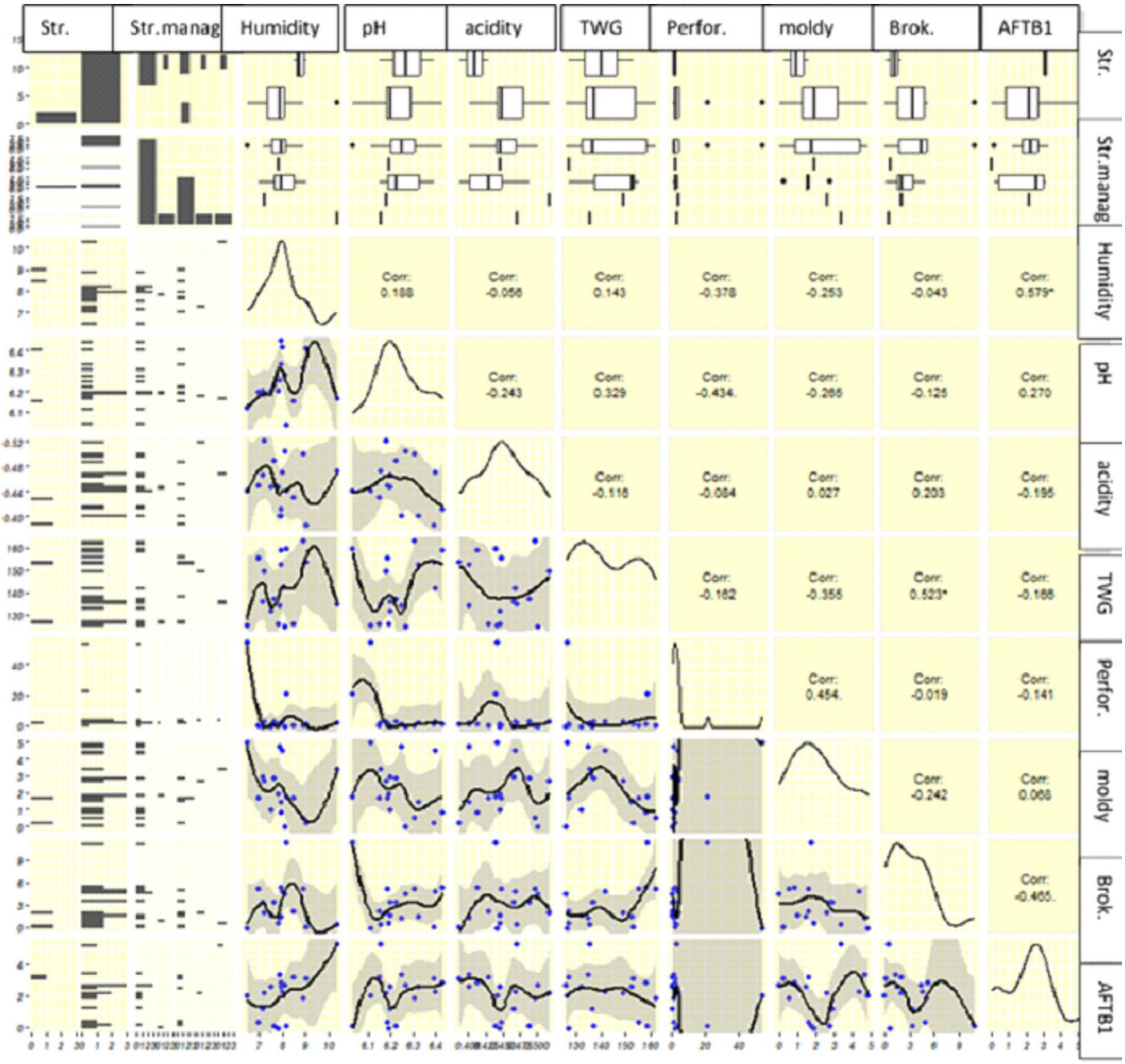
Sanitary quality and physico-chemical characteristics of cowpea stocks: moisture content, pH, acidity, thousand kernel weight, percentages of perforated kernels, moldy kernels, broken kernels and aflatoxin B1 content are recorded in Table 5. Grain moisture ranged from 6.50±0.06 to 10.32±0.07 g/100g DM; pH ranged from 6.04±0.02 to 6.44±0.01; acidity ranged from 0.39± 0.01 to 0.52±0.01%; thousand kernel weight ranged from 126.01±0.95 to 162.39±2.38 g/1000 kernels; the rate of perforated grains from 0.52±0.06% to 53.66±0.19%; the rate of moldy grains from 0.00±0.00 to 4.88±0.29% the rate of broken grains from 0.00±0.00 to 10.98±0.29% and the levels of aflatoxin B1 from 0.00±0.00 to 5.19±0.55 µg/kg (Table 2).

Table 2: Sanitary quality and physico-chemical characteristics of cowpea stocks

Code	Humidity (%)	pH	Acidity (%) MS	TGW g/1000 grains	Perforated grain (%)	Moldy Grain (%)	Broken Grain (%)	AFB1ug/kg MS
FP1Z	8.03±0.06	6.40±0.00	0.47±0.00	142.09±1.77	4.17±1.29	4.41±0.83	4.64±0.13	2.23±0.08
SDF2Z	8.89±0.04	6.31±0.02	0.50±0.07	162.39±2.38	1.10±0.08	0.55±0.13	5.09±0.38	1.81±0.08
SDF3Z	8.12±0.05	6.27±0.01	0.50±0.02	126.01±0.95	0.52±0.06	0.00±0.00	4.43±1.17	2.67±0.23
SDF16Z	7.94±0.14	6.44±0.01	0.41±0.06	158.67±7.20	2.47±0.86	0.89±0.41	5.24±0.52	2.77±0.38
SDF53B	7.89±0.15	6.25±0.00	0.40±0.01	134.97±3.19	1.84±0.56	4.67±1.39	1.31±0.87	3.31±0.08
SDF52B	7.18±0.06	6.20±0.00	0.47±0.00	136.72±3.03	0.94±0.06	2.90±0.43	3.35±0.98	1.19±0.00
SDF10Z	7.68±0.01	6.23±0.01	0.49±0.01	137.59±2.42	3.65±0.18	2.80±0.90	3.41±0.34	0.16±0.23
SDF54B	7.97±0.13	6.33±0.01	0.40±0.00	152.49±2.79	3.38±0.75	1.47±0.86	1.54±0.88	2.55±0.08
SDF11Z	7.84±0.09	6.20±0.01	0.45±0.01	127.18±0.66	2.35±0.00	1.91±0.00	0.68±0.96	0.00±0.00
SDF51B	697±0.00	6.19±0.01	0.45±0.00	155.52±5.26	1.17±0.67	1.66±1.27	4.98±1.15	0.38±0.08
SDF35F	8.48±0.22	6.15±0.01	0.43±0.00	126.90±0.00	0.95±0.98	1.67±0.64	2.08±0.42	3.17±0.00
SDF49B	9.03±0.10	6.40±0.01	0.39±0.01	153.36±2.36	2.58±0.64	0.25±0.08	0.03±0.02	3.02±0.08
B36F	10.32±0.07	6.16±0.00	0.47±0.00	135.74±4.36	3.34±0.51	3.38±1.17	0.41±0.09	5.19±0.55
B41L	8.22±0.09	6.04±0.02	0.44±0.00	159.00±6.4	21.50±1.00	1.77±0.33	10.98±0.29	0.16±0.08
B46L	7.52±0.02	6.20±0.03	0.45±0.03	132.44±3.29	0.95±0.41	1.00±0.24	1.64±0.60	2.60±0.00
SDF50K	7.24±0.05	6.18±0.01	0.52±0.01	149.39±3.26	3.88±0.02	2.65±0.13	1.92±0.20	2.16±0.00
SP55B	6.50±0.06	6.12±0.01	0.44±0.01	126.46±5.72	53.66±0.19	4.88±0.29	0.00±0.00	1.98±0.08

Legend : the first letter indicates the initial of the packaging material,

the number indicates the serial number of the sample,
the last letter indicates the initial of the name of the village



Legend: str. Stor.=storage structure; str. Manag=structure management; TWG=thousand grain weight; perfor.gr.=perforated grain; moldy gr.=moldy grain; brok.gr.=broken grain.

Figure 14 Correlation matrix of variables

The correlation coefficients indicate that there is:

ü a positive correlation between moisture and aflatoxin B1 concentrations; between broken grain rate and thousand grain weight ($P<0.05$);

ü a negative correlation between perforated grain rates and pH, between broken grain rate and aflatoxin B1 concentrations;

ü a positive correlation between moldy grain rates and perforated grain rate ($P<0.1$) (Figure 14).

- **DISCUSSION**

Cowpea is mainly stored in grain form to facilitate packaging and protection of the grain from pests. The dwelling house is the most used storage structure. Zongo et al in 2015 in a study conducted among traders and producers in central Burkina Faso had found that the store was the main storage structure for cowpea with 45% and the house 40% (Zongo et al., 2015). These differences could be explained by the difference in study populations, geographic conditions (rural and urban), and the quantity of stocks. Salifu et al found that cowpeas are stored by 56% of producers in granaries in a study conducted in Ghana (Salifu, 2012); this difference may be explained by the difference in classification of structures. In the study conducted by Salifu, the bag and canister are considered storage structures while in our study they are packaging materials according to the technology described by Cruz (Cruz et al., 2016). The bags are stored with their contents in the storage structure which can be the house or the warehouse. Storage in the dwelling houses could facilitate control but for stocks kept with chemicals, it could lead to discomfort or even poisoning for family members according to several studies (AFSSA, 2013; IARC, 2015; Zongo et al., 2015).

Prior to storage, arrangements are made inside the storage structure either by placing pallets, sprinkling chemicals or other types of arrangements; pallets are the most used in our study; this corroborates other studies that have shown that pallets are used to arrange the inside of storage structures (Cruz et al., 2016; Zongo et al., 2015).

After dehulling, cowpeas are packed in a more or less airtight container before storage in the fitted structure. The use of double-bottom bags is the most common (57.71%); authors have found that airtight packaging using double-bottom bags and PICS bags reduces the activity of pests such as insects in storage, and is a simple and cost-effective means of storage protection (Bradford et al., 2018; FAO/WHO, 2019; Murdock et al., 2003); the use of the double-bottom bag can be explained by its affordable cost compared to the less used PICS bag; and its accessibility although it is less hermetic; this observation was made by several authors who found that the price of 1000FCFA for the PICS bag was high for producers, especially those in Burkina Faso (Dabat, Drabo, Lançon, & Baas, 2010; Sugri et al., 2021; Zongo et al., 2015). Overall, airtight packaging is the most used, this can be explained by its ability to preserve cowpea for longer; this finding was made by Bidzakin in 2022. In this study, he showed that the poly-tank (plastic barrel) is the most preserving packaging material followed by the PICS bag (Bidzakin, Yeboah, Sugri, Graves, & Awunyo-Vitor, 2022).

During conditioning, chemical or natural substances can be added to the cowpea for its protection against the stocks' enemies. In general, the majority of producers (52.19%) use synthetic chemical substances for the conservation of cowpea stocks compared to natural substances (leaves, ash). Our results are superior to those found with producers in the Southern Sudan zone (34% of producers surveyed) by Yamkoulga et al (Yamkoulga et al., 2020). The use of chemical product to conserv cowpeat varied according storage structure ; In the store, a high use of chemical products was noted (88.24% of producers) and 75.48% of producers use chemical product to conserve cowpea in dwelling house. In general, chemical product are most use than natural product while leaf, ash. Limited use of chemicals in the hom may be due to their toxicity and the presence of men in the same home as stocks. Our results are similar to those found by Sugri et al. in Ghana who showed in a study on post-harvest losses that chemicals were used more by producers for stock protection than natural product (Sugri et al., 2021). However, INERA recommends the use of double-bottom bags without preservatives, which is not the case for the producers in this study. Zongo *et al.* reported the use of chemicals not intended for the preservation of agricultural products (Zongo et al., 2015). Salifu Mahama found that 50% of the producers used ash compared to 40% for chemicals; this difference can be explained by the high use of the granary which is suitable for ash use (Salifu, 2012). The use of chemical substances has two purposes, termite control in the development of structures and protection against other insects that develop inside the stocks. The increasing use of chemicals is due to their effectiveness, but it has been shown that misuse of these substances can lead to residues in food and cause health problems (Hammer, Carson, & Ridley, 1999; Kpatinvoh et al., 2017;

Soumanou & Adjou, 2016). Abiotic constraints are encountered during storage including humidity, lack of hygiene, air, delay in harvesting and long storage time. Moisture (44.65% of respondents) is the main factor promoting mold growth; its not difference in moisture impact according storage structure. This corroborates studies by other authors who found that moisture in storage is the primary risk factor for mold growth and aflatoxin production (Chulze, 2010; Wolde, 2017). These authors also showed that toxigenic mold growth occurs at the same time as aflatoxin production (Wolde, 2017).

Biotic constraints (enemies) encountered during storage are insects, rodents molds mainly. Among them rodents and insects were the most incriminated (43.43% and 42.7% of producers respectively). The same observation was made by Yamkoulga et al in 2020 with producers in the Sudanian zone of Burkina Faso, but with a higher percentage than in our study (96%) (Yamkoulga et al., 2020). This result corroborates those of other authors who have incriminated insects as the main pests of stocks (Abraha, Kahsay, Leake, & Gebremedhin, 2018; Kiaya, 2014; Obiedzińska, 2017; Sawicka, 2019). Studies have shown that insects are present in all regions with species diversity (Waongo, Ba, Dabire-Binso, & Sanon, 2015); this could explain their importance in stocks. Pest presence in stocks varied according to storage structure, in house, rodents are most pest infected stoks and in store, insects are pest most incriminated ; this result can be explained by quality of store that may make stocks inaccessible to some enemies such as rodents. In our study, 10.58% of growers found molds to be the pests of stocks compared to 12% in Salifu's study; but our results are of the same order of magnitude as those from that study with insects and rodents as major enemies (Salifu, 2012).

Analysis of physico-chemical characteristics of cowpea samples collected in the sub-Sahelian zone showed that grain moisture ranged from 6.50±0.05g/100 to 10.32±0.05 g/100g the difference in stock moisture can be explained by the diversity of packaging materials, post-harvest practices such as drying. Our values were lower than those found by Houinsou *et al*. in 2014 in Benin (12.079 g/100g) on cowpea seeds preserved with essential oils (Houinsou, Adjou, Ahoussi, Sohounhloué, & Soumanou, 2014). Our values were lower than that set by the Codex STAN 171-1989 standard on cowpea for tropical climate countries (15%) (FAO/OMS, 2007), that of Burkina on cowpea seed (below 12%) (Normes-Burkinabè, 2006). Studies have shown that a stock moisture of 10% was favorable for aflatoxin synthesis by molds (Lavkor & Var, 2017); this could be a risk for aflatoxin contamination of stocks. Bradford et al found that stocks in a PICS bag with a relative humidity of 72%, which corresponds to a product moisture of 13%, significantly reduced mold activity and aflatoxin production (Abalone, Gastón, Bartosik, Cardoso, & Rodríguez, 2011; Bradford et al., 2018; Nganga et al., 2016). Similarly, Cruz et al in 2019 showed that for a temperature of 25°C, the maximum storage moisture of cowpea varied from 13 to 14%. These authors also established the link between storage moisture and aflatoxin contamination (Cruz, Hounhouigan, Havard, & Ferré, 2019).

The thousand-seed weight ranged from 126.01±0.95 g/1000 grains to 162.39±2.38 g/1000 grains. Higher values were reported in 2010 (133 to 177g/1000 seeds) (Ouedraogo, Sawadogo, Tignegré, Drabo, & Balma, 2010). Thousand kernel weights of our samples were lower than the INERA estimate for some freshly harvested varieties as high as 26g/100 kernels or 260g/ 1000 kernels (INERA 2017) and most were lower than those found by Aly et al. (Aly, Ahouansou, Mama, Olou, & Agli, 2017). A decrease in 1000 grain weight could be explained by the presence of internal pests (Fossati, 1995). Thousand kernel weights of our samples were conform to the norms applyed on cowpea in exportation 150 to 200g/1000 grains for first categorie (NBF 01-100 ; 2009). The correlation coefficients indicate that there is a positive correlation between broken kernel rate and thousand kernel weight ($P<0.05$). This is because broken kernels are no longer attacked by internally developing insects that can influence thousand kernel weight; in addition, breakage reduces the inter-kernel space and prevents adult movement in the batch, which would decrease egg laying throughout the batch.

Broken rate ranged from 00.00±0.00% to 10.98±0.29%; perforated grain rate ranged from 0.52± 0.06% to 53.66±0.19%; moldy grain rate ranged from 0.00±0.00% to 4.88±0.29%. Broken rate, perforation rate, and moldy kernel rate are impurities that may be related to biotic factors such as

insects and molds. Correlation analysis with R software (RGui) showed that there is a positive correlation between moldy grain rates and perforated grain rates (P<0.1). This corroborates the finding of some authors that insects disseminate molds on grains and perforations are openings for the proliferation of these molds. The maximum broken kernel rate recommended by the Codex Alimentarius is 3% stan 171-1989 (rev. 1-1995) (FAO/OMS, 2007); this value is similar to that of our study (3.04%). The perforated grain rate of 53.66±0.19% is obtained in cowpea stored in the plastic bag; these rates are lower than those found by Bakoye et al in 2020 with cowpea stored in woven bags and PICS bags for 8 months (Bakoye et al., 2020). This difference can be explained by the storage time of 4.5 months in our study.

The pH varied from 6.04±0.02 to 6.44±0.01; acidity from 0.39±0.01 to 0.52±0.01%. The acidity of our stocks is lower than that set by the Codex Alimentarius for cowpea seeds (0.075 g H2SO4/100g DM); they are also lower than those (0.83±0.10 g H2SO4/100g DM) found in Benin on cowpea seeds preserved using essential oils (FAO/OMS, 2007; Houinsou et al., 2014). The pH values are higher than those found by Casquete et al. in 2017 (pH 5.5) on the conditions of mold growth and aflatoxin production in stocks. In this study, he indicates that optimum aflatoxin production occurs at pH 5.0; 0.95 aw, and a temperature of 25-30°C (Casquete, Benito, Córdoba, Ruiz-Moyano, & Martín, 2017; Tai et al., 2020). Statistical analysis indicates a negative correlation between perforated grain rates and pH (P<0.1). Studies have shown that at pH 4.5 aflatoxin production by aspergillus is high; however, this is also dependent on temperature (30° C) (Das, Angayarkanni, Bhattacharya, & Palaniswamy, 2012); admittedly, our pH values are higher than these values but these conditions may justify this.

Aflatoxin content ranged from 0.00±0.00 to 5.19±0.39 µg/kg DM; the lowest content was obtained in a sample stored in double-bottom bags (SDF11Z) and the highest in a sample stored in plastic drums (B36F). Statistical analysis showed that there is a significant difference between the samples. This difference could be explained by the water content which itself differed between samples, from the packaging material, to the pre and post-harvest practices. Our values were lower than those found on cowpea seeds stored in plastic bags (9.21µg/kg), but the average value (1.93µg/kg) is higher than that found on cowpea seeds stored in peak bags (1.17µg/kg) in Côte d'Ivoire after 4.5 months of storage (Konan et al., 2016). Our values are also lower than those found in cowpea grains stored in three locations in Ibadan State, Nigeria (Ogungbemile, Etaware, & Odebode, 2020). This average value is lower than that found in maize stored in rural households in Malawi (1.71±3.17µg/kg), Zimbabwe (11µg/kg) (Hove, Boevre, Jacxsens, Nyanga, & Saeger, 2016a; Matumba, Monjerezi, Chirwa, Lakudzala, & Mumba, 2009; Misihairabgwi et al., 2019). The contamination rate of our stocks was 94.12%. The number of samples with aflatoxin B1 concentrations above the threshold (2µg/kg) set by regulations for cereals and nuts (Chilaka et al., 2022; FAO, 2004, 2010) accounted for 58.82%.

The contamination rate is lower than that found by Ogungbemile who found 100% of cowpea stocks from three localities in Ibadan State to be contaminated with aflatoxin B1; and all of them had aflatoxin B1 levels above the FAO standards for cowpea (0.30 ± 0.10 µg/g) (FAO, 2011; Ogungbemile et al., 2020) compared to 17.65% in our study. Correlation analysis indicates that there is a positive correlation between moisture and aflatoxin B1 concentrations (P<0.05); this result corroborates the result given by Cruz in 2019 who related cowpea stock moisture to aflatoxin contamination (Cruz et al., 2019). Principal component analysis indicates that cowpea packed in the plastic barrel (polytank) retains its quality better; this corroborates the result found by Bidzakin et al. in 2022 on cowpea preservation techniques (Bidzakin et al., 2022).

- **CONCLUSION**

For their resilience to pest attack, and to preserve sanitary quality of cowpea stocks, producers use some storage practice such as conditionning, structure management, conservative use. These practice varied according to storage structure model. It emerges that the factors which condition the technologies of storage and conservation of the cowpea are the biotic factors such as the insects, the rodents and the molds. They affect the sanitary quality of the cowpea by the perforation of the grains, the production of aflatoxins; then the abiotic factors such as humidity,

the lack of hygiene, the bad practices of harvest; that favors the presence of the biotic factors and the damage that they cause. This could be detrimental to the health of consumers since cowpeas are mostly consumed in collective catering where hygiene measures are often not well respected. Research may continuous to known impact of storage practice on nutritional and toxicological quality of cowpea stocks.

CONSENT

Producer's consent is required and all producers of this study give them consent.

ETHICAL APPROVAL: Not applicable.

REFERENCES

Abalone, R., Gastón, A., Bartosik, R., Cardoso, L., & Rodríguez, J. (2011). Gas concentration in the interstitial atmosphere of a wheat silo-bag. Part I: Model development and validation. *Journal of Stored Products Research, 47*(4), 268–275. doi:10.1016/j.jspr.2011.05.004

ABNORM. (2019). CATALOGUE DES NORMES BURKINABE 2019 In: ABNORM.

Abraha, R. H., Kahsay, Z. A., Leake, G. W., & Gebremedhin, B. W. (2018). Assessment of production potential and post-harvest losses of fruits and vegetables in northern region of Ethiopia. *Agric & Food Secur, 2018*(7), 29. doi:10.1186/s40066-018-0181-5

AFSSA. (2013). *Aflatoxins (sum of B1, B2, G1, G2) in cereals and cereal-derived food products 1*. Retrieved from

Aly, D., Ahouansou, R., Mama, V., Olou, D., & Agli, C. (2017). Evaluation et selection participative des varietés ameliorées de niébé en milieu rural dans le departement de Couffo au Benin. *African Crop Science Journal, 25*(4), 509 - 520. doi:10.4314/acsj.v25i4.8

AOAC. (1990). Official method of analysis, 15th. In A. o. O. A. Chemists (Ed.), (Vol. 04).

Bakoye, O. N., Baoua, I., Seyni, H., Amadou, L., Murdocka, L. L., & Baributsa, D. (2020). Comparative Study of Cowpea Storage Technologies in the Sahel Region of Niger _ Enhanced Reader. *Insects MDPI, 2020*(11), 689.

Bidzakin, J. K., Yeboah, O., Sugri, I., Graves, A., & Awunyo-Vitor, D. (2022). Economics of Bulk Storage Techniques: Maize and Cowpea Storage in Ghana. *Hindawi Advances in Agriculture, 2022* (8953918), 19 doi:https://doi.org/10.1155/2022/8953918

Bradford, K. J., Dahal, P., Asbrouck, J. V., Kunusoth, K., Bello, P., Thompson, J., & Wu, F. (2018). The dry chain: Reducing postharvest losses and improving food safety in humid climates. *Trends in Food Science & Technology, 71* (2018), 84–93. doi:10.1016/j.tifs.2017.11.002

Casquete, R., Benito, M. J., Córdoba, M. d. G., Ruiz-Moyano, S., & Martín, A. (2017). The growth and aflatoxin production of Aspergillus flavus strains on a cheese model system are influenced by physicochemical factors. *American Dairy Science Association, 100*, 1–10. doi:10.3168/jds.2017-12865

Chilaka, C. A., Obidiegwu, J. E., Augusta Chinenye Chilaka, Atanda, O. O., & Mally, A. (2022). Mycotoxin regulatory status in Africa: a decade of weak institutional efforts. *J Toxins, 14* (7), 442.

Chulze, S. (2010). Strategies to reduce mycotoxin levels in maize during storage: A review. . *Food Additives & Contaminants: Part A, 27*(5), 651–657.

Cruz, J.-F., Hounhouigan, D. J., & Fleurat-Lessard, F. (2016). *La conservation des grains après récolte* (Éditions Quæ, CTA, Presses agronomiques de Gembloux ed.).

Cruz, J.-F., Hounhouigan, D. J., Havard, M., & Ferré, T. (2019). La transformation des grains. *Collection Agricultures tropicales en Poche, Quæ, Presses agronomiques de Gembloux, CTA, Versailles, Gembloux, Wageningen. 182 p. + cahier quadri 16 p.*

Dabat, M., Drabo, I., Lançon, F., & Baas, W. (2010). [Innover pour développer les marchés : le cas de la conservation du niébé au Burkina Faso.].

Das, A., Angayarkanni, J., Bhattacharya, S., & Palaniswamy, M. (2012). Quantification of Aflatoxin B1 Produced by Aspergillus flavus MTCC 2798 in Rice Straw under Solid-State Fermentation. *JOURNAL OF PURE AND APPLIED MICROBIOLOGY, 6*(4), 1663-1669.

Dedi, J. K. é., & Diomande, B. (2017). Characterization of the fungal flora of maize grains (Zea mays) intended for the preparation of compound feeding stuffs of poultry. *J International Journal of Biological Chemical Sciences, 11*(6), 2594-2603.
Dohoo, I. R., Martin, S. W., & Stryhn, H. (2009). Veterinary Epidemiologic Research, VER, Incorporated.
EPA. (2021). *Rapport definitifs validé*. Ministère de l'Agriculture et des Aménagements Hydroagricoles
FAO. (2004). *Worldwide regulations for mycotoxins in food and feed in 2003.* . Retrieved from
FAO. (2010). *Lessons learned and practical guidelines*. Retrieved from
FAO. (2011). *The state of food and agriculture*. Retrieved from
FAO. (2018). Mesure des pertes de produits alimentaires. In.
FAO, PAM, & FIDA. (2019). *Analyse des pertes alimentaires: causes et solutions − Études de cas sur le sorgho, le maïs, le niébé au Burkina Faso.* . Retrieved from Licence: CC BY-NC-SA 3.0 IGO.:
Céréales, légumes secs, légumineuses et matières protéiques végétales, (2007).
FAO/WHO. (2019). Hazard Identification and Characterization: Criteria for Categorizing Shiga Toxin–Producing Escherichia coli on a Risk Basis. *Journal of Food Protection,, 82*, 7–21. doi:10.4315/0362-028X.JFP-18-291
Gauthier, A. (2016). Les mycotoxines dans l'alimentation et leur incidence sur la santé. *Sciences pharmaceutiques, 2016*(dumas), 01315198.
Gnonlonfin, G., Hell, K., Adjovi, Y., Fandohan, P., Koudande, D., & Mensah, G. A. (2013). A review on aflatoxin contamination and its implications in the developing world: a sub-Saharan African perspective. *Critical Reviews in Food Science and Nutrition, 53*(4), 349–365.
Gonçalves, P., & Santo, J. D. (2016). *Goncalves et al, 2016*.
Hammer, K., Carson, C., & Ridley, C. (1999). Antimicrobial activity of essential oils and other plants extract. *Journal of Applied Microbiology, 86*, 985-990.
Houinsou, R. d. L., Adjou, E., Ahoussi, E., Sohounhloué, D., & Soumanou, M. (2014). Caractéristiques biochimique et sensorielle du niébé (Vigna unguiculata) conservé au moyen des huiles essentielles extraites de plantes de la famille des Myrtaceae . 428–437.
Hove, M., Boevre, M. D., Jacxsens, C. L. L., Nyanga, L., & Saeger, S. D. (2016a). Occurrence and risk assessment of mycotoxins in subsistence farmed maize from Zimbabwe. . *Food Control, 69*, 36–44.
Hussein, H. S., & Brasel, J. M. (2001). Toxicity, metabolism, and impact of mycotoxins on humans and animals. *Toxicology, 167*(2), 101-134. doi:10.1016/s0300-483x(01)00471-1
IARC. (2012). *Mycotoxins and Human Health*. Retrieved from
IARC. (2015). *Mycotoxin control in lowand middle income countries.* Retrieved from
Keller, B., Russo, T., Rembold, F., Chauhan, Y., Battilani, P., Wenndt, A., & Connett, M. (2022). The potential for aflatoxin predictive risk modelling in sub-Saharan Africa: a review. *World Mycotoxin Journal, 15*(2), 101-118. doi:https://doi.org/10.3920/WMJ2021.2683
Kensler, T., Roebuck, B., Wogan, G., & Groopman, J. (2011). Aflatoxin: a 50-year odyssey of mechanistic and translational toxicology. *Toxicol Sci, 120 Suppl 1*(Suppl 1), S28-48. doi:10.1093/toxsci/kfq283
Kiaya, V. (2014). Post-harvest losses and strategies to reduce them. . *ACF International,, 2018* (01), 1–25.
Kirigia, D., Winkelmann, T., Kasili, R., & Mibus, H. (2018). Development stage, storage temperature and storage duration influence phytonutrient content in cowpea (Vigna unguiculata L. Walp.). *Heliyon, 4* (2018), 00656. doi:10.1016/j.heliyon.2018.e00656
Konan, C. K., Fofana, I., Coulibaly, A., Koffi, E. N., Chatigre, O., & Biego, G. H. M. (2016). Optimization of Storage Methods of Cowpea (Vigna Unguiculata L. Walp) Bagged Pics Containing Biopesticide (Lippia Multiflora) By Central Composite Experimental Design in COTE D'IVOIRE. *International Journal of Environmental & Agriculture Research (IJOEAR), 2*(7), 46-56.
Kpatinvoh, B., Adjou, E. S., Dahouenon-Ahoussi, E., Konfo, T. R. C., Atrevi, B., Soumanou, M. M., & Sohounhloue, D. C. K. (2017). Efficacité des huiles essentielles de trois plantes

aromatiques contre la mycoflore d'altération du niébé

(Vigna unguiculata L., Walp) collecté dans les magasins de vente du Sud-Bénin. *Journal of Applied Biosciences, 109*, 10680-10687. doi:10.4314/jab.v109i1.12

Lavkor, I., & Var, I. (2017). The Control of Aflatoxin Contamination at Harvest, Drying, Pre-

Storage and Storage Periods in Peanut: The New Approach. In A. u. Lukman Bola (Ed.), *Aflatoxin* (pp. Ch. 3). Rijeka: IntechOpen.

Linguya, K., Moraa, O., Wangai, K., & Chao, K. (2015). Potential of intercropping for management of some arthropod and nematode pests of leafy vegetables in Kenya. *Journal of Agricultural Sciences, Belgrade, 60*(3), 301-314. doi:10.2298/jas1503301l

Matumba, L., Monjerezi, E., Chirwa, E., Lakudzala, D., & Mumba, P. (2009). Natural occurrence of AFB1 in maize and effect of traditional maize flour production on AFB1 reduction in Malawi. *African Journal of Food Science, 3*(12), 413–425.

Misihairabgwi, M., Ezekiel, C., Sulyok, M., Shephard, G., & Krska, R. (2019). Mycotoxin contamination of foods in Southern Africa A 10 year review 2007 2016. *Critical Reviews in Food Science and Nutrition, 59*(1), 43-58. doi:10.1080/10408398.2017.1357003

Mostrom, M. (2016). Mycotoxins: Toxicology. *Encyclopedia of Food and Health, Fargo, USA: North Dakota State University*, 43–48.

Murdock, L. L., Seck, D., Ntoukam, G., Kitch, L., & Shade, R. (2003). Preservation of cowpea grain in sub-Saharan Africa—Bean/Cowpea CRSP contributions. *Field Crops Research, 82*(2003), 169–178. doi:10.1016/S0378-4290(03)00036-4

Mutiga, K. S., Vincent, W., Vivian, H., Jagger, H. W., Michael, M. G., & Rebecca, N. J. (2014). Extent and drivers of mycotoxin contamination: Inferences from a survey of Kenyan maize mills. *J Phytopathology, 104*(11), 1221-1231.

Ngamo, L., & Hance, T. (2007). Diversité des ravageurs des denrées et méthodes alternatives de lutte en milieu tropical, . *Tropicultura, 25*, 215-220.

Nganga, J., Mutungi, C., Imathiu, S., & Affognon, H. (2016). Effect of triple-layer hermetic bagging on mould infection and aflatoxin contamination ofmaize during multi-month on-farm storage in Kenya. *Journal of Stored Products Research, 69* (2016), 119e128. doi:10.1016/j.jspr.2016.07.005

Niébé Spécifications, NBF 01-009 C.F.R. (2006).

Obiedzińska. (2017). Impact of food losses and waste on food security. . *Sci J Warsaw Univ Life Sci Warsaw Probl World Agric, 17*(32), 125–141. doi:10.22630/PRS.2017.17.1.12

Ogungbemile, O. A., Etaware, P. M., & Odebode, A. C. (2020). Aflatoxin Detection and Quantification in Stored Cowpea Seeds in Ibadan, Nigeria. *Journal of Biotechnology and Biomedicine, 3*, 010-017.

Ouedraogo, J. T., Sawadogo, M., Tignegré, J.-B., Drabo, I., & Balma, D. (2010). Caractérisation agro-morphologique et moléculaire de cultivars locaux de niébé (Vigna unguiculata) du Burkina Faso. *Cameroon Journal of Experimental Biology, 06*(1), 31-40.

Raiola, A., Tenore, G., Manyes, L., Meca, G., & Ritieni, A. (2015). Risk analysis of main mycotoxins occurring in food for children: An Overview. *Food and Chemical Toxicology, 84*, 169–180.

Salifu, M. (2012). *Comparative assessment of some storage technologies used for cowpea storage in the Nadowli district of the upper west region of Ghana.* (PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN POSTHARVEST TECHNOLOGY), KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Sawicka, B. (2019). Post-harvest Losses of Agricultural Produce. *Springer Nature Switzerland AG 2019 W. Leal Filho et al. (eds.), Zero Hunger*. doi:10.1007/978-3-319-69626-3_40-1

Shephard, G. S. (2008). Impact of mycotoxins on human health in developing countries. *Food Additives and Contaminants, 25*, 146–151.

Sissoko, M., VeroniqueTheriault, & Smale, M. (2021). Le potentiel de developpement du niébé,

au dela de ses grains, dans les marchés locaux du Mali. In USAID (Ed.).
Smith, L., Stasiewicz, M., Hestrin, R., Morales, L., Mutiga, S., & Nelson, R. (2016). Examining environmental drivers of spatial variability in aflatoxin accumulation in kenyan maize: potential utility in risk prediction models. *frican Journal of Food, Agriculture, Nutrition and Development, 16*, 11086-11105.
Soumanou, M., & Adjou, E. (2016). Sweet Fennel (Ocimum gratissimum) Oils. In:Preedy, V.R. (Ed.), Essential Oils in Food Preservation, Flavor and Safety. *Academic Press*, 765–773.
Sugri, I., Mutari, A., Owusu, R. K., & Bidzakin, J. K. (2021). Postharvest losses and mitigating technologies: evidence from Upper East Region of Ghana. *Sustainable Futures, 3*(2021), 100048. doi:10.1016/j.sftr.2021.100048
Tai, B., Chang, J., Liu, Y., & Xing, F. (2020). Recent progress of the effect of environmental factors on Aspergillus flavus growth and aflatoxins production on foods. *Food Quality and Safety, 2020*(4), 21–28. doi:10.1093/fqsafe/fyz040
Udomkun, P., Tirawattanawanich, C., Ilukor, J., Sridonpai, P., Njukwe, E., Nimbona, P., & Vanlauwe, B. (2019). Promoting the use of locally produced crops in making cereal-legume-based composite flours: An assessment of nutrient, antinutrient, mineral molar ratios, and aflatoxin content. *Food Chemistry, 286* (2019), 651–658. doi:10.1016/j.foodchem.2019.02.055
Waongo, A., Ba, N., Dabire-Binso, L., & Sanon, A. (2015). Diversity and community structure of insect pests developing in stored sorghum in the Northern-Sudan ecological zone of Burkina Faso. *Journal of Stored Products Research, 63* (2015), 6e14. doi:10.1016/j.jspr.2015.05.002
Wolde, M. (2017). effects-of-aflatoxin-contamination-of-grains-in-ethiopia. *International Journal of Agricultural Sciences, Vol. 7* (4), 1298-1308.
Wu, F. (2015). Global impacts of aflatoxin in maize: trade and human health. *World Mycotoxin Journal, 8*(2), 137-142. doi:10.3920/WMJ2014.1737
Yamkoulga, M., Waongo, A., Ilboudo, M., Traoré, F., Dabiré-Binso, C., & Sanon, A. (2020). Perceptions des pratiques et contraintes post-récoltes chez les producteurs des principales légumineuses cultivées en zone Sud-soudanienne du Burkina Faso. *Annale de l'Université Joseph KI-ZERBO Série C, 016*.
Zakari, O. A., Baoua, I., Amadou, L., Tamò, M., & Pittendrigh, B. R. (2019). Les contraintes entomologiques de la culture du niébé et leur mode de gestion par les producteurs dans les régions de Maradi et Zinder au Niger. *J International Journal of Biological Chemical Sciences, 13*(3), 1286-1299.
Zongo, S., Ilboudo, Z., Waongo, A., Gnankiné, O., Doumma, A., Sembène, M., & Sanon, A. (2015). Risques liés à l'utilisation d'insecticides au cours du stockage du niébé (vigna unguiculata l. walp.), dans la région centrale du Burkina Faso. *REV. CAMES Science de la vie, de la terre et agronomie, 03*(01).