



Assessment of Cowpea [*Vigna unguiculata* (L), Walp] Storage Technique and some Stocks Sanitary Quality in Center North Region of Burkina Faso

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Authors' contributions

This work was carried out in collaboration among all authors. Author SN did the survey and sampling, drafted the initial manuscript, analyzed and interpreted the results. Author SB contributed to write the manuscript. Author VRK contributed to survey and sampling procedure. Author FHB conceptualized the study and contributed to write the manuscript. Author AS contributed to write the manuscript. Author AS supervised the study. All authors read and approved the final manuscript.

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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 storage structure interior (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 (2µg/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.

1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L), Walp), once considered a food crop, is increasingly becoming both a food and cash crop [1,2]. It is one of the main food legumes produced worldwide [3]. In 2020/2021, cowpea is ranked first among legumes produced in Burkina Faso [4]. Cowpea is one of the main sources of nutrients for populations in West African countries [1, 2, 5]. It plays an important role in achieving food security through its availability during the lean season [6]. 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) [7]. This work has made cowpea one of the most widely produced and consumed legumes in West Africa, and in Burkina Faso in particular [4]. The problems currently facing the agricultural sector, particularly the cowpea sector, are pests and the risks associated with aflatoxin contamination [8]. 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 [7]. 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% [9-14]. 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 [15]. Perforated grains are no longer fit for human consumption [13]. Molds colonize grains either from the field or through the action of rodents and insects during storage [16]. 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) [17-22]. Aflatoxin contamination of crops also leads to huge economic losses in Africa, with export product rejections of 39% [23]. Abiotic spoilage factors include temperature, humidity, pH, as well as poor pre-harvest and post-harvest hygiene; according to several authors, these factors favor mold growth and toxin production [8,24]. Studies shown that cowpea stored in hermetique triple layer bag with moisture inferior to 14% reduced aflatoxin contamination [25]. There is a synergy between biotic and abiotic parameters in aflatoxin contamination of stocks [14, 26]. Studies have shown that temperature and relative humidity are climatic risk variables

for aflatoxin contamination of stocks [12, 14]. Relative humidity and temperature variations influence stock humidity and the growth of mycotoxin-producing molds [26]. Among these toxins, group B aflatoxins are the most harmful to humans and animals, notably aflatoxin B1 [27, 28]. Aflatoxins are responsible for several diseases including liver cancers, intoxications and stunted growth in children according to several studies [29-34]. 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.

2. MATERIALS AND METHODS

2.1 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-Saharan zone 13°05'North 1°05' West	Boussouma	Boussouma, Zikiema
	Korsimoro	Taonsin, Yimiougou
	Pissila	Lebda, Goema, Forgui

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.

2.3 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 sample of 250 producers, following the method of Lwanga described by Dohoo et al. in 2009 [35]. 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 [35].

$$n = \frac{P(1 - P)Z^2}{d^2}$$

Where

n= sample size

Z= confidence interval

P= percentage of producers in the population

D= precision

2.4 Data Collection

Data were collected by administering a 70-question questionnaire to 174 (total of 600 cereal and legum producers) 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 [35].

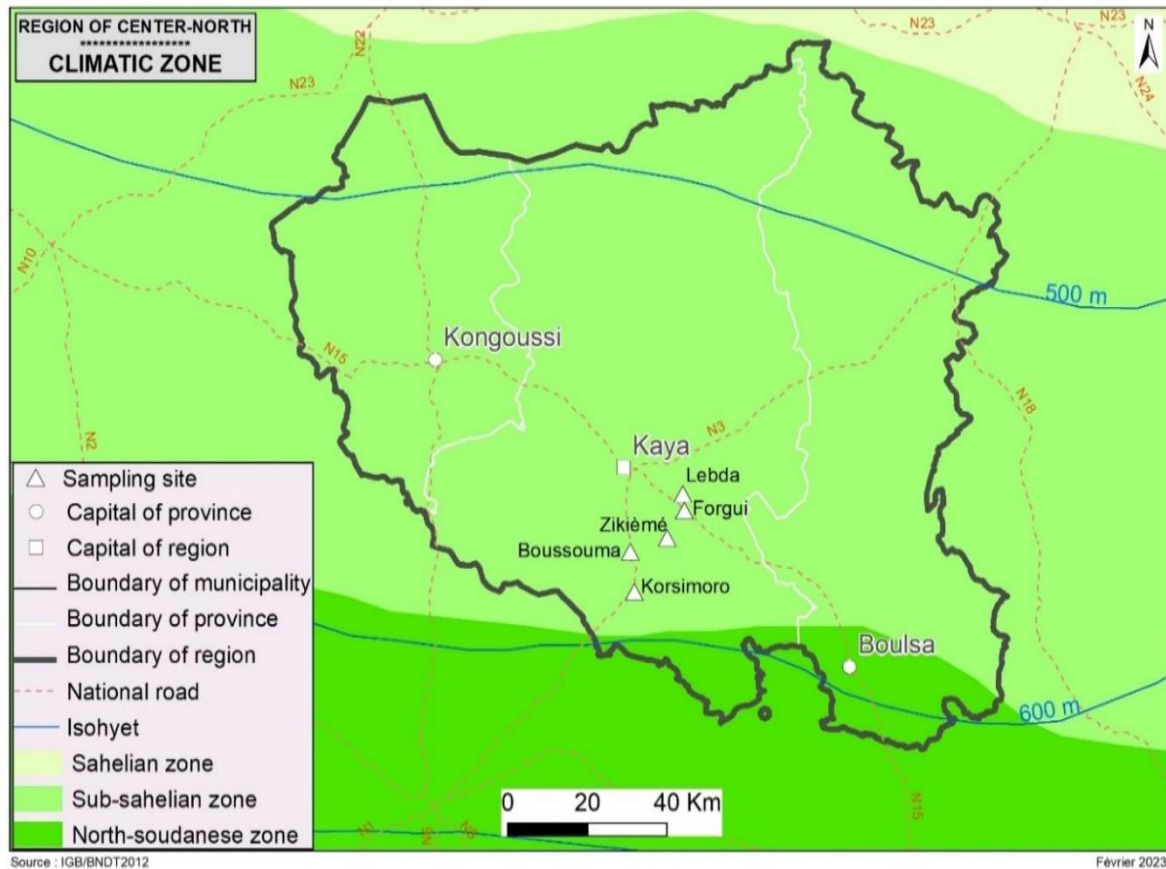


Fig. 1. Map of study area

2.5 Physico-chemical Characteristics

2.5.1 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 (05) 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 :

$$\text{Moisture content(\%)} = \frac{PE - (MF - M0)}{PE} \times 100$$

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

2.5.2 Determination of the weight of 1000 seeds

The weight of 1000 seeds of cowpea samples was determined by the method of Cruz [24]. 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 :

$$Mn = mn \cdot 1000 / 100$$

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 [24].

$$TWG = M = \frac{M1 + M2 + M3}{3}$$

2.5.3 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 [36]. The results are given by the following formulas :

Perforation rate

$$\% \text{ perforated grains} = \frac{\text{perforated grain weight} * 100}{\text{test intake}}$$

Mouldy grain rate

$$\% \text{ mouldy grain} = \frac{\text{mouldy grain weight} * 100}{\text{test intake weight}}$$

Broken grain rate

$$\% \text{ broken grain} = \frac{\text{broken grain weight} * 100}{\text{test intake weight}}$$

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

2.5.4 Determination of pH and acidity

Acidity and pH were determined according to the AOAC method 943.02 [37]. Five (05) 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.

2.5.5 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 [35].
- 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 :

$$AFB1 = \frac{A * D * E}{G} \quad (\text{Expressed in } \mu\text{g/kg})$$

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)

2.6 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.

3. RESULTS

3.1 Cowpea Storage Structures and Type of Storage (Figs. 4 and 5)

Cowpea is mainly stored in grain form (98.28%). The house is the most commonly used storage structure (89.66%).

3.2 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%) (Fig. 4).

3.3 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 (Fig. 5).

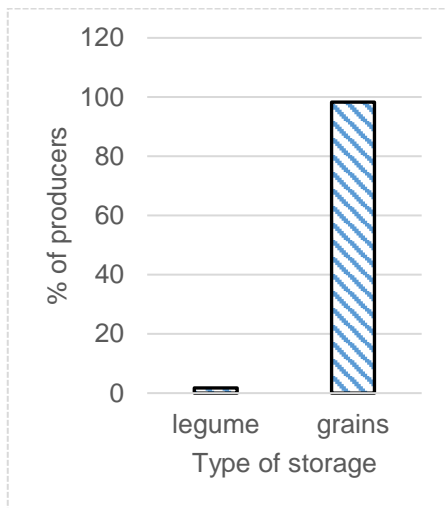


Fig. 2. Type of storage

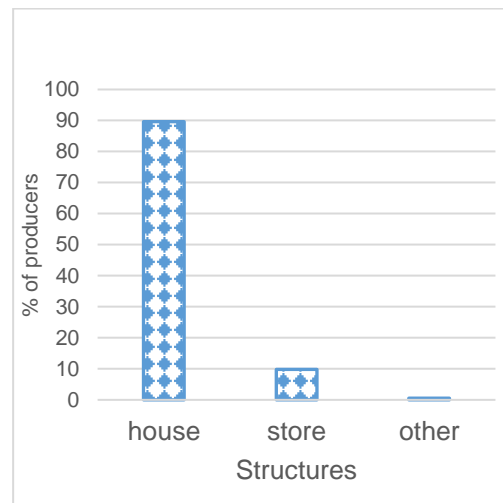


Fig. 3. Cowpea storage structures

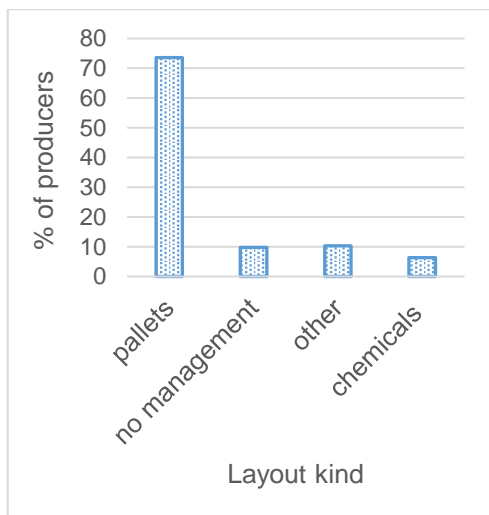


Fig. 4. Internal layout of the storage structure

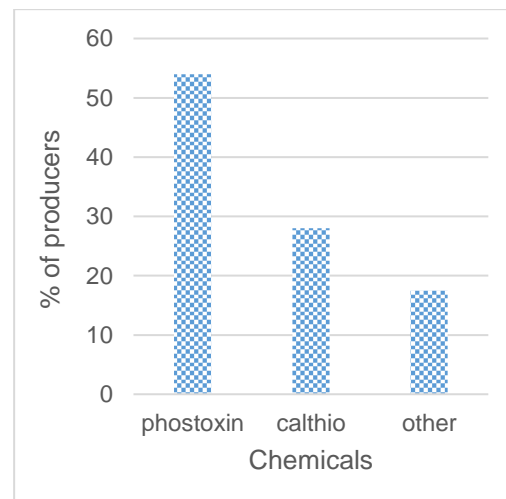


Fig. 5. Chemicals used for internal layout

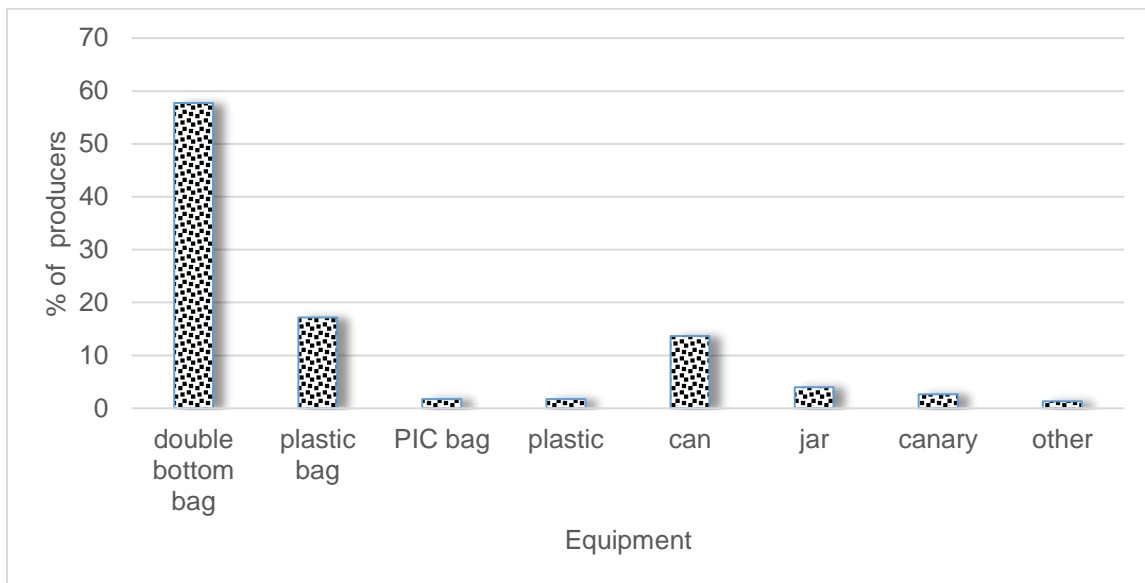


Fig. 6. Packaging equipment

3.4 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%) (Fig. 6).

3.5 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 (Fig. 7).

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

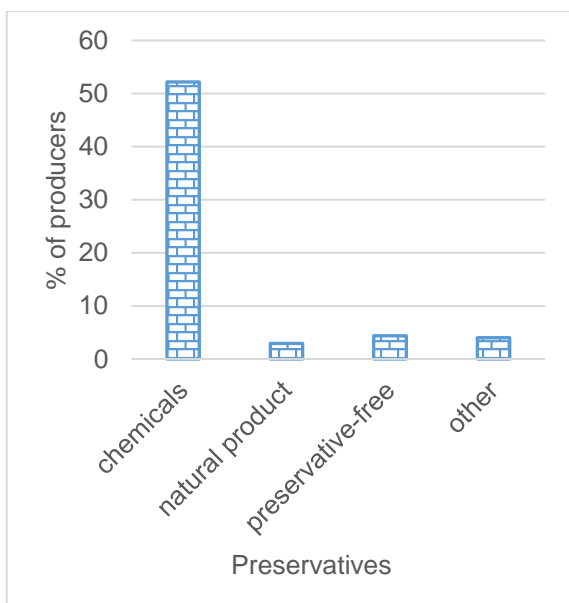


Fig. 7. Cowpea preservatives

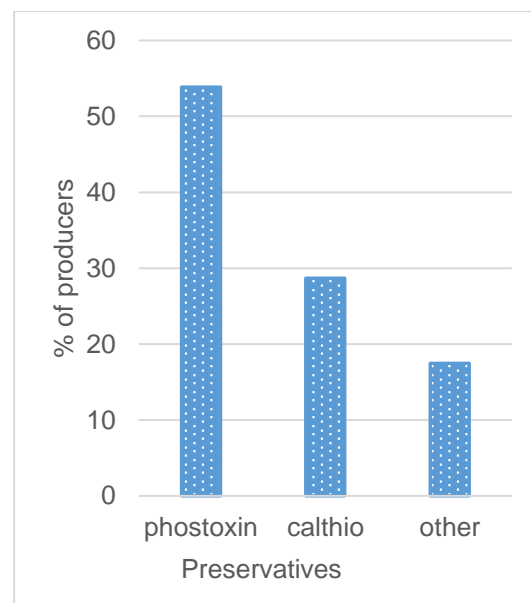


Fig. 8. Chemical preservatives

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	6.97±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*

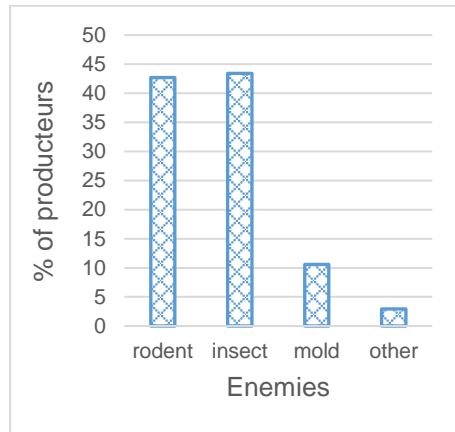


Fig. 9. Enemies of cowpea stocks

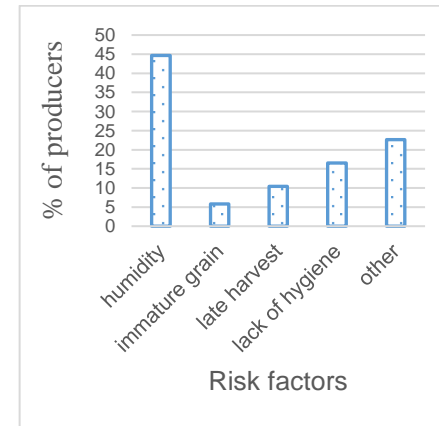


Fig. 10. Abiotic factors affecting cowpeas

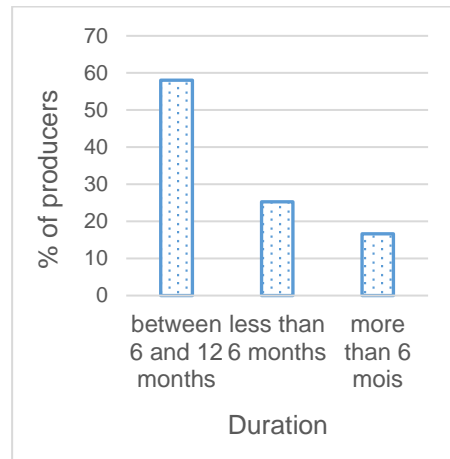


Fig. 11. Cowpea storage life

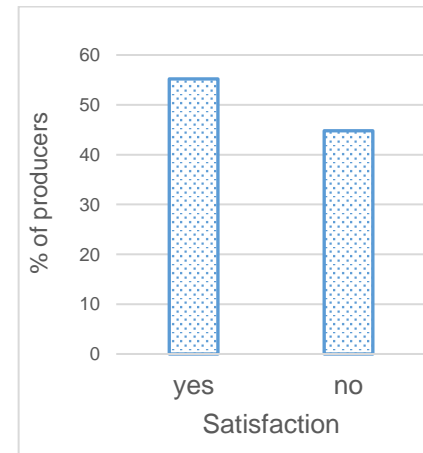


Fig. 12. Satisfaction with preservation techniques

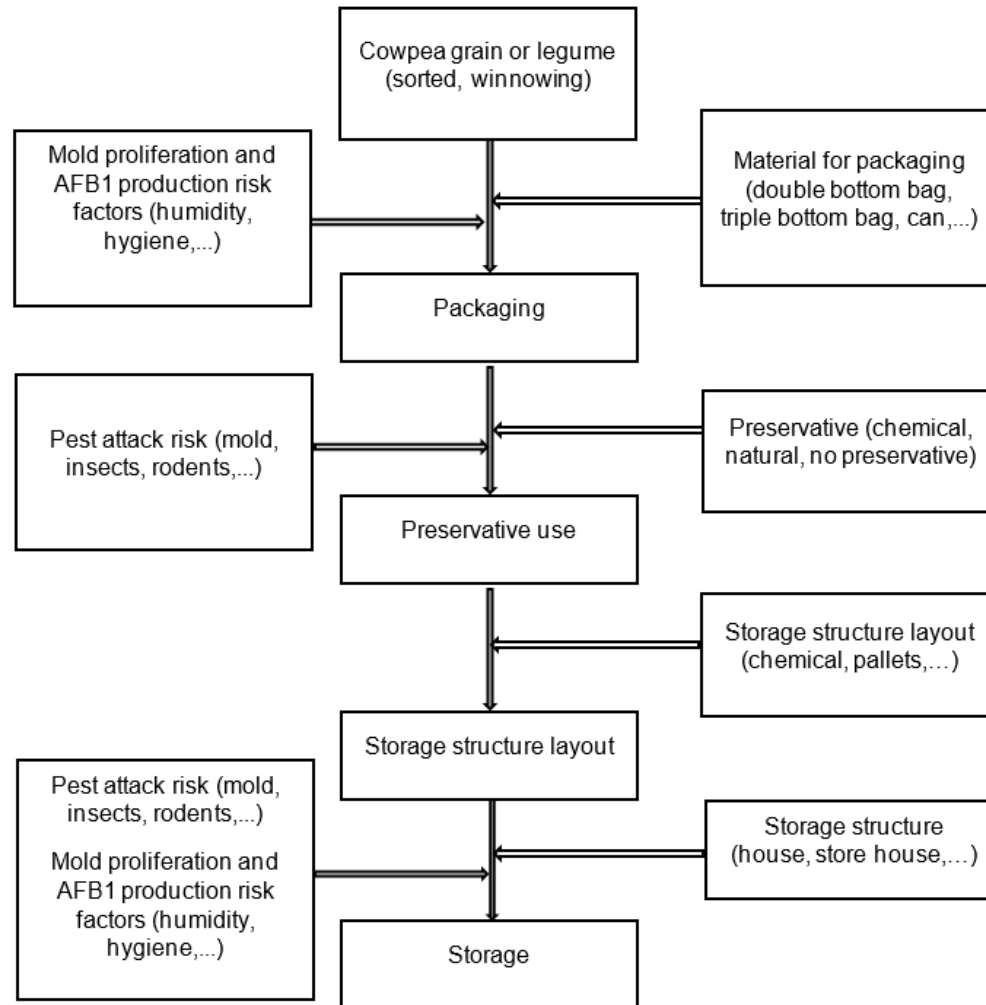


Fig. 13. Diagram of cowpea storage

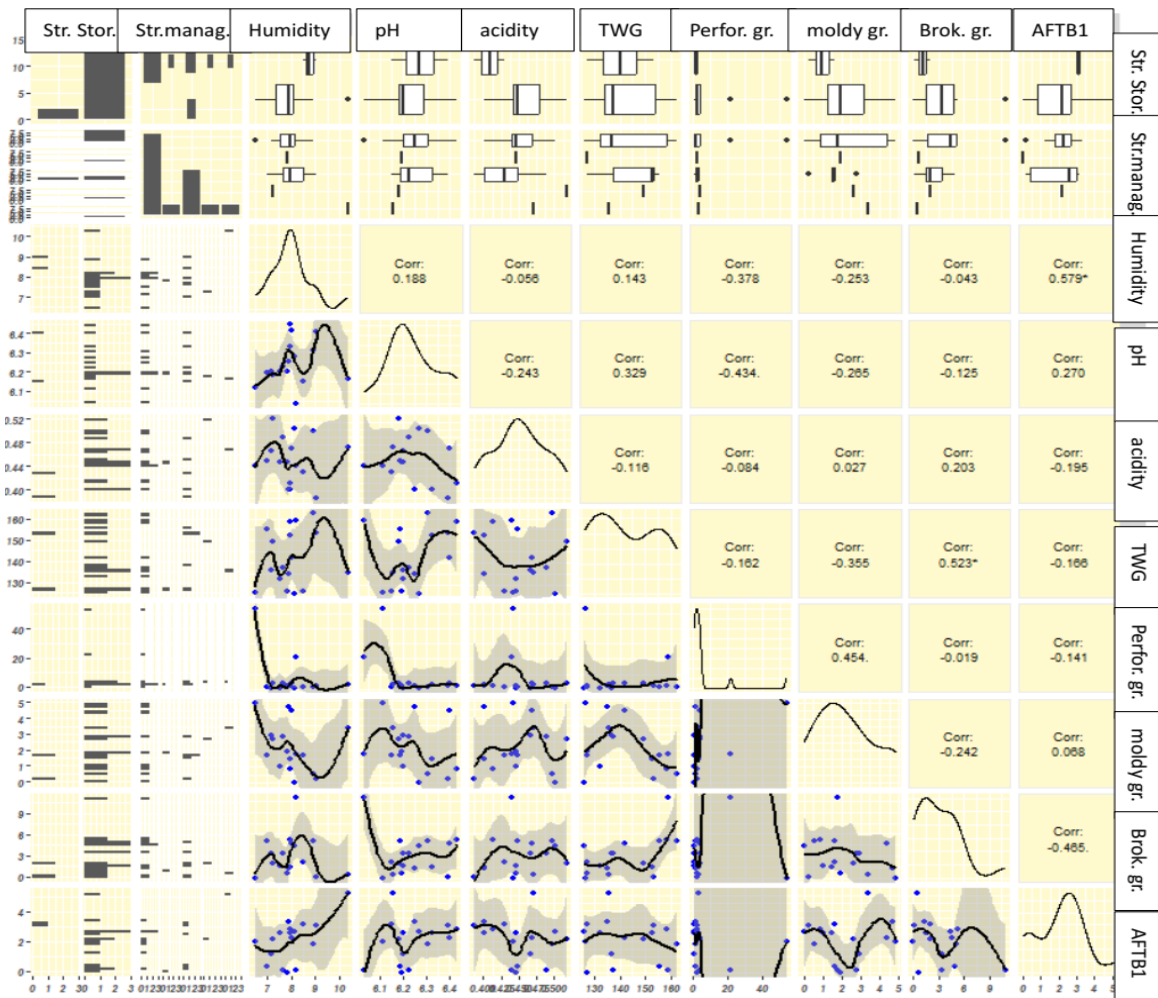


Fig. 14. Correlation matrix of variables

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.

3.6 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 (Fig. 10). Other enemies such as air and animals were cited as pests of stocks.

3.7 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 (Fig. 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.

3.8 Cowpea Storage Life (Fig. 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).

3.9 Satisfaction with Preservation Techniques (Fig. 12)

In general growers are satisfied with their cowpea preservation techniques (55.17%) but

44.83% are not satisfied with their cowpea preservation techniques.

3.10 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 2. 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 $0.52 \pm 0.01\%$; thousand kernel weight ranged from 126.01 ± 0.95 to 162.39 ± 2.38 g/1000 kernels; the rate of perforated grains from $0.52 \pm 0.06\%$ to $53.66 \pm 0.19\%$; the rate of moldy grains from 0.00 ± 0.00 to $4.88 \pm 0.29\%$ the rate of broken grains from 0.00 ± 0.00 to $10.98 \pm 0.29\%$ and the levels of aflatoxin B1 from 0.00 ± 0.00 to 5.19 ± 0.55 µg/kg (Table 2).

The correlation coefficients indicate that there is :

- A positive correlation between moisture and aflatoxin B1 concentrations ; between broken grain rate and thousand grain weight ($P < 0.05$) ;
- A negative correlation between perforated grain rates and pH, between broken grain rate and aflatoxin B1 concentrations ;
- A positive correlation between moldy grain rates and perforated grain rate ($P < 0.1$) (Fig. 14).

4. 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% [38]. 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 [39]; 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 [24]. 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 [29, 31, 38].

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 [24, 38].

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 [7, 10, 26]; 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 [13, 38, 40]. 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 [40, 41]. In this study, he showed that the poly-tank (plastic barrel) is the most preserving packaging material followed by the PICS bag [41].

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 [42]. The use of chemical product to conserve cowpea 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 [13]. 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 [38]. 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 [39]. 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 [43-45]. 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 [46, 47]. These authors also showed that toxigenic mold growth occurs at the same time as aflatoxin production [47].

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%) [42, 48, 49]. This result corroborates those of other authors who have incriminated insects as the main pests of stocks [48-51]. Studies have shown that insects are present in all regions with species diversity [52]; 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 [39].

Analysis of physico-chemical characteristics of cowpea samples collected in the sub-Saharan zone showed that grain moisture ranged from $6.50 \pm 0.05\%$ to $10.32 \pm 0.05\%$ 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%) on cowpea seeds preserved with essential oils [53]. Our values were lower than that set by the Codex STAN 171-1989 standard on cowpea for tropical climate countries (15%) [54], that of Burkina on cowpea seed (below 12%) [55]. Studies have shown that a stock moisture of 10% was favorable for aflatoxin synthesis by molds [28]; 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 [25, 26, 56]. 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 [57].

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) [58]. Thousand kernel weights of our samples were lower than the Agri-Facts estimate for some Bean stocked as high as 200g/1000 kernels to 350g/ 1000 kernels [59] and most were lower than those found by Aly et al. [60]. A decrease in 1000 grain weight could be explained by the presence of internal pests [42]. Thousand kernel weights of our samples were conform to the norms applied on cowpea in exportation 150 to 200g/1000 grains for first categorie [55]. 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 $00.00\pm 0.00\%$ to $10.98\pm 0.29\%$; perforated grain rate ranged from $0.52\pm 0.06\%$ to $53.66\pm 0.19\%$; moldy grain rate ranged from $0.00\pm 0.00\%$ to $4.88\pm 0.29\%$. 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) [54]; this value is similar to that of our study (3.04%). The perforated grain rate of $53.66\pm 0.19\%$ 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 [61,62]. 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 $0.52\pm 0.01\%$. The acidity of our stocks is lower than that set by the Codex Alimentarius for cowpea seeds (0.075 g $H_2SO_4/100$ g DM); they are also lower than those (0.83 ± 0.10 g $H_2SO_4/100$ g DM) found in Benin on cowpea seeds preserved using essential oils [53, 54]. 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 [14, 62]. 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) [63]; 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 $\mu\text{g}/\text{kg}$ 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 ($9.21\mu\text{g}/\text{kg}$), but the average value ($1.93\mu\text{g}/\text{kg}$) is higher than that found on cowpea seeds stored in peak bags ($1.17\mu\text{g}/\text{kg}$) in Côte d'Ivoire after 4.5 months of storage [64]. Our values are also lower than those found in cowpea grains stored in three locations in Ibadan State, Nigeria [65]. This average value is lower than that found in maize stored in rural households in Malawi ($1.71\pm 3.17\mu\text{g}/\text{kg}$), Zimbabwe ($11\mu\text{g}/\text{kg}$) [33, 66, 67]. The contamination rate of our stocks was 94.12%. The number of samples with aflatoxin B1 concentrations above the threshold ($2\mu\text{g}/\text{kg}$) set by regulations for cereals and nuts [23, 68,69] 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 $\mu\text{g}/\text{g}$) [65, 70] 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 [57]. 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 [41].

5. CONCLUSION

For their resilience to pest attack, and to preserve sanitary quality of cowpea stocks, producers use some storage practice such as conditioning, 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 continue to known impact of storage practice on nutritional and toxicological quality of cowpea stocks.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

CONSENT

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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