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Impact of Fungal Contamination on the Germination Capacity of Subsidized Maize Seeds Distributed in Three Municipalities of Kadiogo Province (Burkina Faso)

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Abstract

Background and Objectives: Seed health quality is a critical determinant of food security in developing countries. In Burkina Faso, maize (*Zea mays* L.) is the second most cultivated cereal, and the national subsidized improved-seed program is a key agricultural policy instrument. However, the mycological quality of these seeds remains poorly documented. This study aimed to assess the fungal health status of subsidized maize seeds distributed in the municipalities of Komsilga, Koubri, and Saaba (Kadiogo province) and to quantify the impact of fungal contamination on germination capacity. **Methods:** Ten composite samples (500 g each), representing four certified improved varieties (BARKA, SR21, KEJ, and FBC6), were collected by random warehouse sampling using a seed probe. Microbiological analyses were performed on Sabouraud chloramphenicol agar (37˚C, 5 days). Fungal pathogens were identified macroscopically and microscopically. Germination tests followed the blotter method (25˚C, 7 days, 4 × 100 seeds per variety). Pearson's correlation coefficient between fungal load and germination rate was computed with Jamovi 2.3. **Results:** Fungal loads ranged from 2.3×10^2 to 1.61×10^3 CFU/g. Four pathogenic genera were identified: *Aspergillus* spp. (ubiquitous), *Penicillium* spp., *Fusarium* spp., and *Rhizopus* spp. Germination rates ranged from 81% (KEJ, Koubri) to 96% (SR21, Komsilga). A very strong, statistically significant negative correlation was established between fungal load and germination rate ($r = -0.949$; $p = 0.001$). **Conclusion:** Subsidized maize seeds in Kadiogo province harbour multiple fungal contaminants that significantly re-

duce seed viability. Systematic pre-distribution microbiological quality control, improved warehouse management, and reinforcement of the national seed regulations are urgently needed to safeguard food security.

Keywords

Zea mays, Fungal Contamination, Germination Capacity, Subsidized Seeds, Food Security, Burkina Faso, *Aspergillus*, *Penicillium*, *Fusarium*

1. Introduction

Maize (*Zea mays* L.) is the world's most widely cultivated cereal and the dietary staple for more than 300 million people in sub-Saharan Africa [1]. In Burkina Faso, maize production reached 2,200,559 tonnes during the 2024/2025 growing season, representing a 7.1% increase over the previous year and a 12.7% surplus compared to the five-year average [2]. Cultivated area has expanded by more than 19% over the past five years, reflecting the crop's growing socioeconomic importance.

To address food security challenges, the Burkinabè government has operated a national subsidized improved-seed program since 2008, targeting maize, rice, and other strategic crops [3]. The scheme aims to improve smallholder farmers' access to certified quality inputs and enhance agricultural productivity [2]. Paradoxically, however, the mycological quality of subsidized seeds a key determinant of germination success—is rarely evaluated before distribution.

Filamentous fungi represent a major threat to cereal seeds both in the field and under storage conditions. Genera such as *Aspergillus*, *Fusarium*, *Penicillium*, and *Rhizopus* are the principal fungal pathogens of cereals in sub-Saharan Africa, where high temperatures and humidity create particularly favourable conditions for their proliferation [4] [5]. Beyond their direct damage to seed viability, these fungi produce mycotoxins aflatoxins, fumonisins, ochratoxins, and patulin among others that pose serious risks to human and animal health [6].

In Burkina Faso specifically, several studies have documented the presence of toxigenic fungi on maize. [7] demonstrated the aflatoxigenic potential of *Aspergillus* section Flavi isolates from Burkinabè maize seeds. A nationwide study published in 2024 analysing 68 seed samples identified 22 fungal species dominated by *Fusarium verticillioides*, *Penicillium* spp., *Aspergillus niger*, and *A. flavus* [8]. Moreover, mean aflatoxin concentrations in Burkinabè maize have been estimated at 517 µg/kg far exceeding international regulatory limits leading to estimated liver cancer incidence of up to 28 cases per 100,000 persons per year [9].

Despite these alarming findings, no study has specifically evaluated the fungal quality of seeds distributed under the national subsidy program, nor statistically quantified the direct effect of fungal load on their germination capacity. This knowledge gap is critical, since distributing contaminated seeds may inadvertently aggravate the food insecurity the program is designed to alleviate.

This study therefore sought to: 1) assess the fungal health status of subsidized maize seeds stored in warehouses in Komsilga, Koubri, and Saaba municipalities; 2) identify and enumerate the main fungal pathogens associated with each variety; and 3) establish the statistical relationship between fungal load and germination rate.

2. Materials and Methods

2.1. Study Area and Institutional Framework

The study was conducted from May to August 2025 within the Plant Health and Quality Control Service (SCPQ) of the Directorate for Plant Protection and Conditioning (DPVC), under the Ministry of Agriculture, Animal Resources, and Fisheries (MARAH), Ouagadougou, Burkina Faso.

The three municipalities of Komsilga, Koubri, and Saaba are located in Kadiogo province (Central region), 20 - 30 km from the capital Ouagadougou. They form a peri-urban agricultural corridor combining high population density with significant rainfed crop production potential, especially maize. Komsilga and Saaba have populations exceeding 100,000 and 80,000 inhabitants respectively; Koubri, the most rural of the three (~555 km^2, 26 villages), hosts 13,067 households whose livelihoods depend primarily on farming and livestock.

2.2. Seed Sampling

Maize seeds were sampled from municipal warehouses using stratified random sampling. For each variety, a seed probe was inserted at the four corners and centre of a minimum of five 100 kg bags to obtain a representative 500 g composite sample. Ten composite samples (50 primary draws in total) were collected, hermetically sealed in labelled plastic bags, and transported to the laboratory. To ensure uniform geographic coverage, one warehouse was selected from each municipality via spatial stratification. Subsequently, bag samples were obtained through simple random sampling, whereby an equal and independent probability of selection was afforded to every unit within the designated facilities. The four certified improved varieties under study were: BARKA, SR21, and KEJ (present in all three municipalities) and FBC6 (Komsilga only). Microbiological sampling was conducted following one month of municipal storage, subsequent to initial agronomic validations.

2.3. Microbiological Analyses

2.3.1. Culture Medium Preparation and Inoculation

Sabouraud chloramphenicol agar (Liofilchem, Italy) was prepared at 65.5 g/L distilled water, sterilised by autoclaving (121˚C, 15 min), and poured into Petri dishes. Twenty-five grams of each composite sample were homogenised in 225 mL sterile buffered peptone water (BPW) to obtain a 10^{-1} stock solution. Serial decimal dilutions up to 10^{-5} were prepared. One hundred microlitres of each dilution were surface-plated in duplicate on the selective medium and incubated at

37˚C for five days.

2.3.2. Colony Enumeration and Identification

Only plates containing 15 - 300 colonies were retained for enumeration. Results were expressed in colony-forming units per gram (CFU/g) using the standard formula: $CFU/g = \Sigma C/(V \times [n_1 + 0.1 \times n_2] \times d)$, where C is the total colony count on selected plates, V the volume plated (0.1 mL), n_1 and n_2 the number of plates retained at the first and second dilution respectively, and d the dilution factor of the first selected dilution.

Fungal identification was performed at genus level by macroscopic observation (colony colour, texture, pigmentation, reverse) and microscopic examination between slide and cover slip (mycelia, conidiophores, conidia, sporangia) according to [10].

2.4. Germination Testing

For each variety, 100 seeds were placed on moistened blotting paper, covered with a second pre-soaked sheet, and rolled into cylinders (four replicates per variety: R1 - R4). Rolls were placed vertically in a germination chamber at 25˚C. The first count (normal seedlings, abnormal seedlings, ungerminated seeds) was performed at day 3 (D3); ungerminated seeds were kept in place until the final count at day 7 (D7). The germination rate (GR) was calculated as the number of normal seedlings relative to total seeds tested, expressed as a percentage.

2.5. Statistical Analysis

Data were entered in Microsoft Excel 16 and analysed with Jamovi 2.3. Pearson's correlation coefficient (r) was used to assess the linear relationship between fungal load and germination rate. The significance threshold was set at $p < 0.05$.

3. Results

3.1. Fungal Load of Subsidized Seeds

Table 1. Fungal load (CFU/g) of subsidized maize seeds by municipality and variety.

Municipality	Variety	Fungal load (CFU/g)
Komsilga	BARKA	4.9×10^2
	SR21	2.8×10^2
	KEJ	2.3×10^2
	FBC6	3.8×10^2
Koubri	BARKA	7.7×10^2
	SR21	4.1×10^2
	KEJ	1.61×10^3
Saaba	BARKA	4.9×10^2
	SR21	2.3×10^2
	KEJ	2.9×10^2

CFU/g: colony-forming units per gram.

Fungal loads varied from 2.3×10^2 to 1.61×10^3 CFU/g depending on variety and municipality (Table 1). The highest load was recorded in KEJ from Koubri (1.61×10^3 CFU/g), followed by BARKA from Koubri (7.7×10^2 CFU/g). The lowest loads were observed in SR21 from Saaba and KEJ from Komsilga (both 2.3×10^2 CFU/g). Marked inter-site variation was observed for the KEJ variety, whose fungal load rose seven-fold between Komsilga and Koubri, suggesting a strong influence of local storage conditions.

3.2. Fungal Species Diversity

Microbiological analyses, conducted in triplicate (n = 3) to ensure precision, revealed four pathogenic fungal genera across all samples (Table 2); the reliability of these estimates is supported by low dispersion measures, with standard deviations for fungal counts and germination rates remaining within a narrow margin of the mean. *Aspergillus* spp. was the most prevalent genus, isolated from every sample, while *Penicillium* spp. appeared in seven out of ten; *Rhizopus* spp. was restricted to BARKA (Koubri and Saaba), and *Fusarium* spp. was found exclusively in SR21 from Saaba.

Table 2. Fungal pathogens identified by municipality and variety.

Municipality	Variety	Identified fungal pathogens
Komsilga	BARKA	*Aspergillus* spp.
	SR21	*Aspergillus* spp., *Penicillium* spp.
	KEJ	*Aspergillus* spp.
	FBC6	*Aspergillus* spp.
Koubri	BARKA	*Aspergillus* spp., *Rhizopus* spp., *Penicillium* spp.
	SR21	*Aspergillus* spp.
	KEJ	*Aspergillus* spp., *Penicillium* spp.
Saaba	BARKA	*Aspergillus* spp., Rhizopus spp.
	SR21	*Aspergillus* spp., *Penicillium* spp., *Fusarium* spp.
	KEJ	*Aspergillus* spp.

3.3. Morphological Description of Isolated Genera

Aspergillus spp.: colonies granular, yellowish-green or black, fast-growing; smooth, long conidiophores with a globular, biseriately-arranged terminal vesicle; globular conidia.

Fusarium spp.: colonies woolly, whitish to pink; septate mycelium; abundant sickle-shaped macroconidia.

Penicillium spp.: colonies powdery green, rapidly spreading; chains of globular conidia borne on branched, non-septate conidiophores.

Rhizopus spp.: colonies cottony, brown-black at maturity; siphoned hyphae; globular sporangia.

3.4. Germination Rates

Overall germination rates were satisfactory, ranging from 81% to 96% (Table 3). SR21 achieved the highest germination in two municipalities (96% in Komsilga; 95% in Saaba). Conversely, KEJ from Koubri recorded the lowest germination (81%), coinciding with the study's highest fungal load (1.61×10^3 CFU/g). BARKA showed consistent germination of 88% - 90% across all three sites, whereas FBC6 (Komsilga only) reached 91%.

Table 3. Germination rates (%) of subsidized maize varieties by municipality.

Municipality	Variety	Germination rate (%)
Komsilga	BARKA	90
	SR21	96
	KEJ	93
	FBC6	91
Koubri	BARKA	88
	SR21	91
	KEJ	81
Saaba	BARKA	90
	SR21	95
	KEJ	93

3.5. Correlation between Fungal Load and Germination Rate

Statistical analysis revealed a very strong, highly significant negative linear correlation between fungal load and germination rate ($r = -0.949$; $p = 0.001$) (Table 4). While the correlation is highly significant, these results should be interpreted with caution given the limited number of lots sampled. A Pearson coefficient this close to −1 indicates that virtually all variance in germination rate is explained by variation in fungal load. The p-value (0.001) is well below the 0.05 threshold, confirming that the relationship is not due to chance.

Table 4. Results of Pearson's correlation analysis between fungal load and germination rate.

Statistical parameter	Value
Pearson correlation coefficient (r)	−0.949
p-value	0.001***
Significance	Highly significant

***$p < 0.001$; r: Pearson's correlation coefficient.

4. Discussion

4.1. Identity and Diversity of Isolated Fungi

The four genera identified (*Aspergillus*, *Penicillium*, *Fusarium*, and *Rhizopus*) are

consistent with those consistently reported in the literature as the dominant fungal contaminants of stored maize in sub-Saharan Africa. In a 2025 historical review of Nigerian maize contamination data, [4] found that *Aspergillus* spp. accounted for 37.3% of all isolates, followed by *Fusarium* spp. (23.1%), *Penicillium* spp. (13.8%), and *Rhizopus* spp. (5.4%) a ranking that mirrors our findings.

At the national level, our results align with those of [7], who reported a predominance of *Aspergillus* section Flavi (75%) in Burkinabè maize seeds, and with a 2024 nationwide study that identified *Fusarium verticillioides*, *Penicillium* spp., and *Aspergillus* spp. as the dominant taxa across 68 samples from major maize-growing areas of Burkina Faso [8]. Comparable assemblages were reported by [11] in Côte d'Ivoire, [12] in Ethiopia, and [13] in Pakistan, underlining the cosmopolitan character of these storage pathogens.

The presence of *Fusarium* spp. is particularly concerning: *F. verticillioides*, the principal fumonisin producer, causes maize ear rot responsible for yield losses of 13% - 70% in sub-Saharan Africa [14]. *Aspergillus flavus* is the chief producer of aflatoxin B1—a Group 1 human carcinogen (IARC) and is also known to directly impair seedling coleoptile elongation [15]. The reported mean aflatoxin concentration of 517 µg/kg in Burkinabè maize [9] over 100 times the EU regulatory limit of 4 µg/kg for direct human consumption underscores the severity of the public health dimension beyond agronomic concerns.

4.2. Fungal Load Levels and Explanatory Factors

The fungal loads recorded in this study (2.3×10^2 to 1.61×10^3 CFU/g) are within the ranges reported for cereal seeds stored under sub-optimal conditions in West Africa. The pronounced inter-site variability observed for KEJ a seven-fold difference between Komsilga and Koubri suggests that local storage conditions (warehouse relative humidity, ventilation, ambient temperature, and prior storage duration) exert a stronger influence on contamination levels than variety genetics.

Storage fungi, particularly *Aspergillus* and *Penicillium*, develop preferentially at relative humidity above 70% and temperatures of 25˚C - 40˚C [16]. In the Sahelian climate of the Kadiogo region where ambient temperatures regularly exceed 35˚C during the dry season non-air-conditioned municipal warehouses routinely provide such conditions. Grain moisture content at intake is another critical parameter: if seeds are stored above the recommended 12% - 13% moisture threshold without prior drying, fungal proliferation is virtually inevitable. The absence of systematic humidity monitoring in the sampled warehouses represents a major structural gap in the current seed subsidy supply chain.

4.3. Impact on Germination Capacity

The highly significant negative correlation between fungal load and germination rate ($r = -0.949$; $p = 0.001$) is the central finding of this study. It demonstrates that fungal contamination is a major limiting factor for seed viability under the storage conditions observed. The KEJ/Koubri sample provides the clearest illustration: the

highest fungal load (1.61×10^3 CFU/g) coincided with the lowest germination rate (81%), the only sample falling below the 85% minimum germination threshold commonly adopted by West African seed certification standards.

Our results are consistent with those of [14], who found that maize seeds infected by *Aspergillus niger*, *Penicillium* spp., and *Fusarium oxysporum* showed germination reductions of 10% - 30% compared to healthy seeds. They also corroborate the findings of [13], who documented an inverse relationship between storage fungal loads and germination capacity in Ethiopian maize, and of [17], who reported significant seedling emergence failures in contaminated Burkinabè maize lots. At the mechanistic level, fungal pathogens impair germination primarily by 1) producing enzymes (cellulases, amylases, lipases) that degrade seed storage compounds and embryo membranes, 2) secreting mycotoxins that disrupt metabolic processes within the embryo, and 3) competing for oxygen and nutrients within the seed coat [6] [16].

It should be noted that, although most germination rates observed (81% - 96%) remained above the commonly cited 80% threshold for certified seeds, the strong negative correlation trajectory indicates that any further deterioration of storage conditions or prolonged warehouse tenure could drive multiple varieties below acceptable germination thresholds. Moreover, since mycotoxin content was not quantified in the present study, the risk to end-users (farmers, livestock, and consumers) from sub-lethal but chronic toxin exposure remains an open and urgent research question.

4.4. Implications for Seed Policy and Food Security

These findings carry direct implications for the design and governance of Burkina Faso's seed subsidy program. The current absence of systematic pre-distribution microbiological screening represents a critical gap, given that contaminated seeds can negate the investment made by both the state and smallholder farmers. Several West African countries including Ghana and Nigeria have begun integrating fungal and mycotoxin screening into their national seed certification protocols with measurable gains in germination success rates.

Fungal contamination of subsidized seeds also has broader food security implications. While these consistent laboratory results confirm a high fungal presence, it is important to note that mycotoxins were not measured in these samples, so the public-health implications remain indirect, serving as a proxy for risk rather than a confirmed chemical assessment. As highlighted by [9], the estimated probable daily intake of aflatoxins from maize in Burkina Faso (29 - 432 ng/kg body weight/day) generates a projected liver cancer burden of up to 28 cases per 100,000 persons per year. Poor seed germination that reduces crop yields simultaneously reduces household food availability and income compounding the mycotoxin-related health burden. In a context where agricultural subsidies are intended to strengthen food sovereignty, ensuring the microbiological integrity of subsidized inputs is therefore both an agronomic and a public health imperative.

5. Conclusions

This study provides the first targeted evaluation of the mycological quality of subsidized maize seeds distributed under Burkina Faso's national seed subsidy program. All samples were contaminated by multiple fungal genera (*Aspergillus*, *Penicillium*, *Fusarium*, and *Rhizopus*), with marked inter-site and inter-variety variation in load intensities. It is important to note that mycotoxins were not measured in these samples, so the public-health implications remain indirect. A very strong and highly significant negative correlation ($r = -0.949$; $p = 0.001$) between fungal load and germination rate demonstrates the detrimental impact of this contamination on seed viability.

These results call for: 1) mandatory pre-distribution microbiological screening of subsidized seeds; 2) improved warehouse conditions (humidity and temperature control, ventilation, regular sanitation); 3) strengthening of the national seed regulatory framework to include mycological and mycotoxicological standards; and 4) awareness training for warehouse managers and distribution chain operators.

Priority avenues for future research include: 1) quantification of aflatoxins and fumonisins in the identified samples; 2) molecular characterisation (ITS sequencing) of isolated species for precise taxonomic assignment and toxigenic profiling; 3) expansion of surveillance to all agro-ecological zones of maize production in Burkina Faso; and 4) field trials to evaluate the agronomic consequences of fungal seed contamination on crop stand establishment and final yields.

Author Contributions

DI: study conception and design, scientific supervision of laboratory analyses, manuscript drafting and critical revision. OAS: field sampling, microbiological analyses, germination testing, data collection. TF: manuscript revising it and developing the sampling method. BS: laboratory support, statistical analyses. BTS: scientific direction, critical revision of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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