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Deterioration of maize seeds (*Zea mays* L.) during storage: Evaluating quality components of grains under conservation

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Abstract

In tropical Africa, several vulnerable communities are facing seed insecurity, impairing food security. The conservation, good management, and maintenance of seed quality are thus major issues in seed security, especially since the quality of the latter is altered over time. It therefore becomes interesting to conduct research on the evolution of seed deterioration during storage. The main objective of this work was therefore to determine the deterioration rate of maize seeds (*Zea mays* L.) by assessing the quantity of viable seed in a seed lot. In order to achieve this, an experimental study was carried out on the measurement of the components of seed quality, including germination rate, vigour, specific purity, health status and percentage of deterioration. In order to assess the evolution of the above-mentioned quality components, various tests were carried out on seeds of two maize varieties (CHC 201 and CHC 203) stored for 6 months, 1 year and 2 years in warehouses in the Western highlands agroecological zone of Cameroon. The results revealed a significant difference between seeds stored for 6, 12 and 24 months for each of the quality components. Seeds that are stored more longer have low quality. Several significant correlations were observed between the quality variables of seeds under storage. Seven intra-parasitic fungi were identified, with a more marked diversity for seeds stored for 12 months. Although *Aspergillus* ssp. 1 was the fungus attacking the most each of the studied varieties, the CHC 201 variety was the most attacked by fungi during storage compared to CHC 203 variety.

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Introduction

Maize (*Zea mays* L.) is an annual plant belonging to the Poaceae family. It was discovered in the Tehuacan and Guilá Naquitz areas of Mexico approximately 10,000 years ago (Piperno and Flannery, 2001; Smith, 2001). Maize is now the most geographically widespread crop with an environmental adaptation unmatched by any other crop (Tripathi *et al.*, 2011). Thus, maize is cultivated as a cereal for its starchy grains, but also as a fodder plant (Undie *et al.*, 2012). It is therefore virtually recognized as a staple ingredient in the diet of humans and animals, providing up to 30% protein, 60% energy and 90% starch according to Belel *et al.* (2014). With more than 1,137 million tons produced during the 2017-2019 season, maize is currently the cereal with the highest production volume in the world, ahead of wheat and rice (Erenstein *et al.*, 2022). Around 60% of world production is provided by two countries: USA (361 million tons per year) and China (259 million tons per year) (Erenstein *et al.*, 2022). South Africa (17.1 million tons per year) and Nigeria (12.74 million tons per year) are the top leading African producers (Wossen *et al.*, 2023; Mangani *et al.*, 2025). Considered as one of the most important sources of carbohydrates in sub-Saharan Africa, maize is the most cultivated and consumed cereal in the five agro-ecological zones of Cameroon (Mbah *et al.* 2023). Cameroon, being a developing country and in its race for emergence by 2035, it has mentioned as an objective in the document of national development strategy in 2030 to reduce poverty to a socially acceptable level and achieve food security and self-sufficiency households and the nation. Since seeds are an essential element of agricultural campaigns, seed security is recognized as one of the components of food security for vulnerable communities (Michael, 2010). Seeds are then considered a vital input for agricultural production and seed quality is the sum of four basic attributes that are physical, physiological, genetic, and health status (Abdul-Baki, 1980; Bierhuizen and Feddes, 1973; Haim, 2007). The unmet energy needs of the Cameroonian population are due to the low yield of agricultural production systems, one of the main causes of which is the quality of the seeds used in the production process. Seeds generally used in production are seeds that have been stored for a certain period of time. Indeed, the seeds produced are generally kept temporarily to wait for the opening of a new agricultural campaign to allow their sale on the market or their introduction into the production campaign. In addition, the seeds present on the market are not always completely sold during the agricultural campaign and are therefore put on sale again during the following agricultural campaigns. However, it is known that the quality of seeds deteriorates with aging (Kains and Mcquesten, 1948; Michael, 2010). Thus, the objective of this study is to measure the quality variables of the seeds of two varieties of maize stored in warehouses for 6, 12 and 24 months in order to assess the effect of the duration of conservation on these quality variables.

Materials and methods

Plant material

The plant material consisted of two maize varieties, CHC 201 and CHC 203, that were ambiently conserved for 6, 12 and 24 months, CHC standing for "Cameroon Highland Composite". These two varieties were produced by the Agricultural Research Institute for Development and are the most yielded and produced in the Highland region of Cameroon

Measuring variables and procedures

The seed quality components that are germination percentage, vigor, weight purity, degree of deterioration and health status were respectively measured using a germination test by counting the number of germinated seeds out of a total of 100 seeds, a germination vigor test by measuring the length of the main root 8 days after setting seeds in germination conditions, a purity test by calculating the proportion of pure seeds on a sample of 1 kg of seed, a deterioration test which determines the proportion of non-germinated seeds and abnormal seedlings, and a health status test. The health status here consists of identifying the different fungi associated with each seed lot. To do this, 100 maize seeds were randomly taken from each lot and were plated separately in 9 cm Petri dishes containing Potato Dextrose Agar (PDA) culture medium. The dishes were then kept for 4 days, after which the fungi grown on the medium were isolated and inoculated at a rate of two replications per fungus into new Petri dishes containing culture medium. Fungal growth in each of the replications was observed under a light microscope and the identification of the fungi was carried out using the identification keys.

Statistical analysis

The analysis of results focused on the data revealed by direct measurements of the components of seed quality. To assess the effect of storage duration on each of the components of seed quality, the ANOVA test was used with separation of means through the LSD test. Pearson correlation coefficients between the different components of seed quality were established, each with the significance level at 5% threshold. These descriptive and inferential statistical analyses were carried out using SPSS statistical software, version 23.0 and Excel spreadsheet, version 2019.

Results

Quality Components of seeds according to storage duration

Analysis of variance revealed a significant difference between each of the different quality components of seeds (germination percentage, vigour, purity, and deterioration percentage) for conservation duration (Fig. 1). The LSD method allowed us to highlight the differences within each of the components (Fig. 1). The germination rates of CHC 201 and CHC 203 seeds stored for 6 months, 98.01% and 99.12%, respectively, differed from those stored for 12 months, 95.18% and 95.13% respectively (Table 1). Similarly, those stored for 12 months differed from those stored for 2 years, which were 90.34% and 59.31%, respectively (Table 1). The average lengths of the radicles of the seeds of CHC 201 and CHC 203 stored for 6 months, 13.32 cm and 13.96 cm respectively, show a significant difference from those of seeds stored 12 months, which are 9.59 cm and 10.96 cm (Table 1).

Table 1. Mean values of each component of seed quality for 6, 12 and 24 months conservation duration for the two analysed maize seed varieties

Variety	Variables	Conservation duration		
		6 months	12 months	24 months
CHC 201	Germination (%)	98.01 ± 0.23a	95.18 ± 0.74b	90.34 ± 1.25c
	Radical length (cm)	13.32 ± 0.37a	9.59 ± 0.59b	8.50 ± 1.60b
	Purity (%)	98.60 ± 1.82a	97.70 ± 1.82a	86.00 ± 1.47b
	Deterioration (%)	4.10 ± 0.11c	12.07 ± 0.09b	20.26 ± 0.15a
CHC 203	Germination (%)	99.12 ± 0.03a	95.13 ± 0.44b	59.31 ± 0.04c
	Radical length (cm)	13.96 ± 0.59a	10.96 ± 1.97b	9.86 ± 0.58b
	Purity (%)	94.10 ± 3.22a	86.30 ± 1.72b	73.05 ± 0.35c
	Deterioration (%)	6.13 ± 0.05a	10.22 ± 0.14b	19.98 ± 0.09c

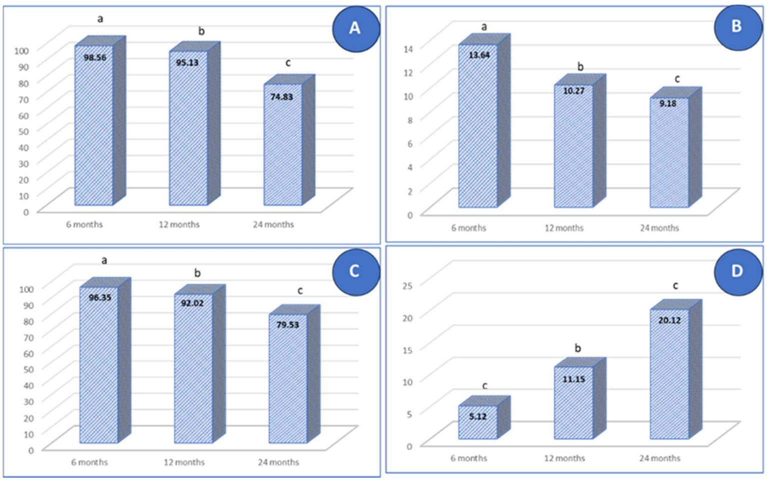

Fig. 1. Evolution of germination percentage (%, A), principal root length (cm, B), seed purity (%, C) and seed deterioration according to conservation duration. For each quality variable, different letter indicates significant difference at p = 5%.

Table 2. Pearson correlations coefficients between component of seed quality of maize seed under ambient conservation

	Conservation duration	Germination	Radical length	Purity	Deterioration
Conservation duration	1	-0.769**	-0.754**	-0.581*	0.593**
Germination		1	0.497*	0.705**	0.545**
Radical length			1	0.317*	-0.801**
Purity				1	-0.336*
Deterioration					1

* : significant at P=0.050 ; ** significant at p=0.010

Table 3. Occurrence (over 4) of fungi species for each maize seen variety and for 6, 12 and 24 months ambient conservation

Fungal	CH201			CH203		
	6 months	12 months	24 months	6 months	12 months	24 months
Aspergillus spp1	4	2	4	3	4	0
Aspergillus spp2	0	2	2	0	2	0
Cercospora sp	0	4	1	0	1	0
Fusarium spp1	0	3	1	0	1	0
Fusarium spp2	3	2	1	0	0	1
Penicillium sp	0	4	3	1	0	2
Rhizopus sp	1	2	0	4	1	2
Fungal richness	3	7	6	3	5	3

On the other hand, there is no significant difference between those stored for 12 months and those stored for 24 months, whose average length is 8.50 cm and 9.86 cm respectively (Table 1). No significant difference was observed for seed purity at 6 months (98.60%) and 12 months (97.70%) of storage for CHC 201 variety. This decreases significantly for the seed stored for 24 months (86.00%). For the CHC203 variety, Table 1 shows the purity for seeds stored for 6 months (94.10%) is significantly higher than the purity of seeds stored for 12 months (86.30%), also significantly higher than the purity of seeds that are stored for 24 months (73.05%). The percentages of deterioration of seeds of CHC 201 and CHC 203 stored for 6 months, which were respectively 4.10 and 6.13% are significantly different with those stored for 12 months, whose percentages are 12.07 and 10.22% (Table 1). There was also a difference in the deterioration of seeds stored for 12 months and those stored for 24 months, with deterioration percentages of 20.26 and 19.98%, respectively (Table 1).

Correlations between components of seed quality

Seed conservation duration was significantly and negatively correlated with germination percentage (r=-0.769), vigour (r=-0.754), and seed purity (r=-0.581). However, conservation duration was significantly and positively correlated with seed deterioration (r=0.593, Table 2). The correlation between seed deterioration and average radicle length was negative and significant (r=-0.801; p<0.010), as was the correlation between seed deterioration and seed germination percentage (r=-0.754, p<0.010, Table 2). A positive correlation was observed between mean radicle length and germination rate (r = 0.497, P < 0.050), as was the correlation between germination rate and seed purity (r = 0.705, P < 0.010, Table 2).

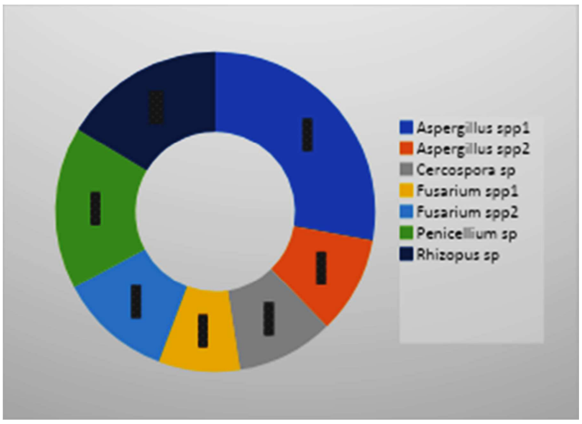

Fig. 2. Occurrence (over 4) of fungi species in maize seeds under ambient conservation

Seed health: Intraparasitic fungal examination

Seed health examination enabled the identification and appreciation of the occurrence frequency of the fungi species recorded based on seed storage duration. Seven fungal strains were recorded: *Fusarium* spp. 1, *Fusarium* spp. 2, *Cercospora* sp., *Aspergillus* spp. 2, *Rhizopus* sp., *Penicillium* sp., and *Aspergillus* spp. 1. These fungi are found in almost all ages of seed conservation and on the two maize varieties studied, with the exception of *Cercospora* sp., *Fusarium* spp.1 and *Aspergillus* spp.2 which were not noticed in seeds stored for 6 months. For a one-year storage period, a very high fungal diversity was observed, meaning the presence of all 7 fungi recorded. The fungi with the widest range of distribution are *Aspergillus* spp.1, *Penicillium* sp. and *Rhizopus* sp., with *Aspergillus* spp.1 the most frequent fungus found in maize seeds stored at room temperature (Fig. 2). CHC 203 seeds have a low level of infection compared to CHC 201 (Table 3).

Discussion

In this research, we investigated the effect of storage duration on the quality components of maize seeds stored under ambient conditions for 6, 12, and 24 months. Germination percentage is the ratio of seeds that produce normal seedlings under optimal laboratory conditions over the total seeds put in germination conditions (ISTA, 2022). Vigor refers to the rapid and uniform emergence of normal seedlings (Brits *et al.*, 2015). Our results showed that the germination percentage and vigour of the maize seeds decreased significantly with storage duration. Significant differences were then observed for germination percentage, vigor, and other seed quality traits in the different storage periods. Germination percentage and vigour of seeds decreased as the seeds were stored for a longer duration. This result is in agreement with those of Abadia *et al.* (2024) in *Zea mays*, Verma *et al.* (2003) in *Brassica campestris* and Basra *et al.* (2003) in cotton, who demonstrated that seed germination and seedling establishment (vigour) are decreased with increasing seed storage duration. Our findings are in agreement with those of Joa Abba and Lovato (1999), who associated reduced germination and weak seedling growth with a long storage period. Regarding the CHC 201 variety, our results show that seeds stored for two years maintain a germination rate higher than the minimum value required for certification in Cameroon (80%). Thus, based on the germination rate, some seeds stored for two years can continue to be sold on the market. The results of the purity analysis show a decrease in purity depending on the storage duration. This decrease is mainly due to seed deterioration observed over time. Embryonic respiration leads to dehydration of seeds, which then become more fragile and susceptible to be damaged due to the loss of tissue cohesion (Throneberry and Smith, 1955). A very high level of impurity was observed in our samples, as inert matter was not considered the only impurity element, as is the case for seed certification authorities. In addition to this element, we also added partially or completely damaged seeds as elements of seed impurity. While our data reveal a significant correlation between germination capacity and seed vigor (r=0.497), this conclusion differs from that of Marcos-Filho (2015), who found no relationship between germination capacity and seed vigour. Seven fungi species were isolated in maize seeds under conservation in this study. The most prevailing were *Aspergillus* spp., *Fusarium* spp., *Penicillium* spp. and *Rhizopus* spp. These results follow those of Sadia *et al.* (2021), who also reported seven fungi species in maize seeds varieties under conversation with *Aspergillus*, *Fusarium*, *Penicillium* and *Rhizopus* being among the most prevailing. Goko *et al.* (2021) also reported these fungi species in maize seeds under conservation in Zimbabwe. Although Deepavali and Nilima (2013) isolated eight fungal species from stored maize seeds, *Aspergillus* sp. was the most dominant fungi as reported in this study. Christensen (1987) reports that *Aspergillus*, *Penicillium* and *Fusarium* are fungal genera typically associated with stored grains, corroborating with our findings. Studies of Sitara and Akhtar (2007) documented that main maize seed storage mycoflora include *Aspergillus* sp., *Fusarium* sp., *Rhizopus* sp. and *Penicillium* sp. and are in the frontline with results of the present study.

Conclusion

Maize seed showed loss of quality with the increase in storage duration under ambient conditions. Maize seeds preserved ambiently are highly infested with a number of fungal seed-borne pathogens and are likely to affect the germination capacity of the seed. Seven fungal species were identified in the study. *Aspergillus* sp. are the most dominant storage fungi, followed by *Fusarium* sp., *Penicillium* sp. and *Rhizopus* sp. that were isolated in this study. Findings of the present investigation will be helpful for designing proper management of maize seed during conservation.

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