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Diversity of Maize Seed Storage and Conservation Systems in Ivory Coast and the West African Subregion: Review of the Synthesis

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Abstract: ***The rapid growth of the African population makes food self-sufficiency a major issue in agricultural policies. In order to have food available throughout the year, traditional and improved storage methods to extend the shelf life of products have been developed. These methods differ little from one country to another. The objective of this study is to synthesize the storage and preservation structures for maize seed used in West Africa. In short, three maize storage systems are used, depending on climatic conditions, population structures and their socio-cultural heritage, and the nature and quality of available materials. These include: open storage systems (used in humid areas of the country, for seeds with a high moisture content (greater than or equal to 14%) in order to complete the drying process), closed storage structures (used in dry areas of the country) and semi-open storage systems (widespread in the semi-arid regions of Africa). The conservation techniques used are firstly drying (in the field, on a rack, on the ground, and above the hearths), then the use of endogenous products (wood ash, petroleum, diesel oil, neem extract and others) and the use of chemical pesticides. As for the alteration of the quality and quantity of stored maize, it is linked to biochemical (chemical reactions within the grain) and biological (insects and other microorganisms) factors that cause serious losses at a time when the production system can hardly compensate for them. In conclusion, in order to store and preserve corn properly, it is more than necessary to follow good storage and preservation practices. These include good maize harvesting practices, good maize storage practices, stock monitoring and maintenance of storage facilities.***

Keywords: Maize, Seeds, Storage, Conservation, Diversity, Methods, Techniques, West Africa

1. Introduction

In Africa, agriculture remains the most important economic sector. It contributes at least 40% of exports, 30% of GDP, 30% of foreign exchange earnings and 70-80% of employment. It helps reduce poverty and promotes economic growth through its contribution to GDP, employment and trade. It remains the main source of income for 90% of the rural population (**Alessandro and *al.*, 2008**).

The rapid growth of the African population makes food self-sufficiency a major challenge for agricultural policies. Subsistence agriculture is practiced by a majority of small-scale farmers. Wide yield gaps and poor soils, as well as other constraints such as abiotic and biotic add to the difficulty of practicing profitable sustainable agriculture (**Macauley and Ramadjita, 2015**). In order to have food available throughout the year, some traditional storage methods to extend the shelf life of produce have been developed. These traditional technologies generally implemented for food preservation, are often inadequate with risks of storage infestation by insect pests of stocks where their presence results in infestation of various toxigenic molds especially Aspergillus (**Fandohan and *al.*, 2003; Gandaho and *al.*, 2017**). Thus, 25% of the world's crops are contaminated with mycotoxins from toxigenic molds; resulting in the reduction of the amount of food available globally (**Yiannikouris and Jouany, 2002**). Food preservation involves the measures taken to maintain foods with the desired properties or nature for as long as possible.

Each year, an estimated 25 to 33 percent of the world's cereal crops, including seeds, are lost in storage, which has a significant impact on global food security. This impact is even greater in food-deficit developing countries, where farmers struggle to preserve their seeds, a key input for food crop production. Cereal storage is the preservation of cereal seeds under controlled environmental conditions in order to preserve the quantity and quality of cereals over long periods between harvest and use (**FAO, 2019**).

This study is focused on a literature review of various maize preservation methods both traditional and modern involving the advantages and disadvantages.

2. Diversity of maize seed storage systems in West Africa

In Africa, according to **Gwinner and *al.* (1991),** three maize storage systems are used depending on the climatic conditions; the structures of the populations and their socio-cultural heritages; the nature and quality of the materials available; and the type and nature of the commodities to be stored (cereals, legumes, or tubers): open storage systems, closed storage structures and semi-open storage systems.

- Open storage systems are used in humid areas of the country, for seeds with high moisture content (greater than or equal to 14%) to complete drying. Maize cobs are placed on rooftops or on a wooden platform in the field, or stored in bunches or sprouts and hung on branches or over fireplaces (**Alzouma, 2001**).
- Closed storage structures (banco granaries, metal or plastic drums, sacks and underground structures) are used in the dry areas of the country. The round or square granaries generally rest on stones or on a wooden platform that forms the base of the granary (**Alzouma, 2001**).
- Semi-open storage structures: These are storage structures that are widespread in the semi-arid regions of Africa. They are granaries made of grass straw called seccos (**Alzouma, 2001**). They are a sort of large basket, placed on a wooden platform a few dozen centimeters (30-40 cm) above the ground, and covered with a thatched roof.

In Côte d'Ivoire, maize seed is most often stored in granaries, polypropylene bags and canaries (**Figure 1**). The granary is most often elevated (covered with straw, 40 cm high and 20 cm in diameter, and the atmosphere is not modified) with a temperature that varies between 22.94° and 28.23°C. This practice allows the completion of drying by natural ventilation. The bags are closed and placed in a room where the atmosphere is not modified with a temperature between 20.40° and 27.27°C. The bags are placed on boards so that they do not touch the walls or any other structure of the room to avoid insect attacks. The canaries are clay pots of spherical shape, closed and placed in a room where the atmosphere is not modified with a temperature that varies between 20.43° and 27.27°C (**Deffan, 2016**). Also, in the savanna zone, maize is frequently stored in the open in garlands, with the cobs tied two by two by their spathes and attached to a rope directly hung in a tree or suspended from a crossbeam resting on vertical stakes. It can also be stored in closed granaries made of cylindrical banco, isolated from the ground and covered with straw (Senufo, Lobbi, Baoulé type) or braided and resting on a raised platform (Malinké granaries, in the northwest of the country). In this zone, it is most often stored in spathe, but sometimes dehulled or shelled (stored in sacks). In the forest zone, maize is sometimes stored in garlands, but more frequently in kitchen granaries (raised rooms in rectangular huts made of slats) or in stores made of banco or cement. It is almost exclusively stored on undehorned cobs (**Ratnadass and Sauphanor, 1989**).

A storage system consists of a storage structure and a conservation measure with the aim of protecting stocks from attack by various pests (**Arouna and *al.*, 2011**). There are also a multitude of traditional granaries in South Benin that are generally categorized into two groups (**Diop and *al.*, 1997; Adégbola and Fandohan, 2001**): the "Ago" type and the "Ava" type. The "Ago" type structures are found in southern Benin. The conical roof of these granaries is made of straw (Imperatacylindrica). The rectangular or circular cage is made of branches or ribs of the oil palm (Elaeisguineensis). The "Ava" type granaries have a straw roof. The undesired maize cobs, piled up and carefully arranged in layers, define a large cylinder that serves as a cage. For improved granaries, two types of structures have been introduced:

- The roof is made of straw in which an opening is created for loading. The circular cage is usually made of woven bamboo or mallotus (a kind of straw). Another opening is also created in the cage to facilitate unloading. The platform is most often flat and sometimes conical and is supported by feet (7 to 9 in number) equipped with an anti-rat device made of sheet metal. These feet, about two meters high, are soaked with drain oil (to fight against termites) before being put in the ground; and
- Improved earthen granaries: they are also protected by a straw roof. The cage is a body made of kneaded termite mound earth and consolidated by chopped soft grass. It takes the shape of a jar and is provided with draining valves in its lower part. The platform is a flat, low base, usually made of cement. In southern Benin, this type of granary was introduced in the departments between the 7th and 8th parallels (Couffo, Zou and Plateau). Maize is stored as grain with a moisture content of 13% or less (**Fandohan, 2000**).

In Togo, several systems are used to store and preserve maize (Huidza or Pidza, Ava, Sogba, tank, Adjoko and silos) (**Figure 2**), the most commonly used of which are Ava and Huidza (**Akpavi and *al.*, 2007**). The Ava type granary is one of the oldest endogenous storage and conservation systems; it is much more widely used in areas where sheep and goat movement is controlled. It allows for better conservation of natural resources (**IPGRI, 1999; Engels and *al.*, 2001**). The Huidza type granary is a kind of large bottomless basket with a diameter of up to 1.5 m and a height of up to 2 m. It is made of stalks and a wooden frame. It is made from stems of Mallotusoppositifolus (Geisel) Müll. Arg, A. indica, M. thonningii or Bambusa vulgaris Schrader ex Wendel. Much more modern, this granary protects the crops against thieves and animals (sheep, goats, etc.). It contributes more to environmental degradation than other types of granaries because the removal of plant material for its construction is more important. Nevertheless, it remains the most widely used type of granary (**Akpavi and *al.*, 2007**).

In Burkina Faso, the storage structures commonly used in the various villages are represented by granaries, stores and houses (**Figure 3**). It should be noted that maize is stored either with the cob in storage structures such as the granary, in the form of grains in bags in structures such as the store, and in mixed form (cob, grains) in homes (**Somda, 2016**).

In Benin, there are different traditional and improved maize storage structures namely: traditional granaries made of plant materials, traditional granaries made of earth, improved traditional granaries made of materials and plants, improved traditional granaries made of earth, metal silos and PICS bags (**HELVETAS, 2016**). But the good practices and conditions of use of these improved structures are not mastered by all the main actors in the production chain, which are farmers and extension agents.

Figure 1: Modes of grain storage in Côte d'Ivoire (**Deffan, 2016**): **1a**: Storage of maize grains in a canary; **1b**: Storage of maize cobs in an earthen granary

Figure 2: Storage structure in Togo (**Akpavi and*al.*, 2007**): **2a** "Ava" type granary at home; **2b** Huidza type granary made with bamboo slats (Bambusa vulgaris).

Figure 3: Example of maize storage structures in Burkina Faso (**Somda, 2016**): **3a**: Banco granary;**3b**: Bagged storage in a dwelling house; **3c**: Straw granary

Figure 4: Example of maize storage structures in Benin (**HELVETAS, 2016**): 4a: Traditional plant granary; **4b**: Earthen granary on the ground; **4c**: Improved earthen granary; **4d**: Metal silos

Variability of maize seed saving techniques in West Africa
There is a diversity of traditional and improved methods of maize conservation techniques in West Africa.

The techniques of conservation of the corn in Togo are done by the use of biological and chemical pesticides. Thus, at the time of the installation of the granary, one sprays by successive stages, various products varying according to the operator and according to the means, of the extract of neem, the pesticides of synthesis, while passing by oil mixed with sand, salt water, salt of kitchen or ash. It must be recognized that the use of neem extract, a biological method, is still in its infancy in the area. It deserves to be encouraged because of its proven effectiveness against pests (**Mazhar, 1999; IPGRI, 2001**).

In contrast, maize conservation techniques in Benin are based on a variety of endogenous products. These products, which vary from one area to another, have both preventive and curative effects against pests. The most widely used products are wood ash, petroleum, gas oil and water from the distillation of palm wine (**Arouna, 2002**).

Techniques for drying maize seeds
In Senegal, some producers first spread maize cobs on racks installed over a fireplace, kitchen, and hut for further drying (**Figure 4**) (**Gueye and *al.*, 2012**).

In Benin, drying is variously practiced by producers (**Gandaho and *al.*, 2016**). In Banikoara, the 10% of households that carry out this operation justify their behavior by a strong attachment to respecting the recommendations for drying standing grain in the field. By doing so, they no longer waste time after harvesting to make the product available, for which there is a fair amount of demand on the market. Also, in Gogounou, the Parakou market forces producers to sell their corn quickly. It is in this context that only 29% of producers dry their corn in the field. In Kandi, the situation is similar, but with an early harvest that leads producers to spread the corn on the ground for better drying (**Gandaho and *al.*, 2016**).

Figure 5: Maize cob drying technique (**Gueye, 2012**): **5a**: Maize cobs dried in fodder; **5b**: Piles of maize in spathes at the beginning of harvest; **5c**: Cobs hung over a hearth;

3. The factors of alteration of the quality and quantity of maize grains linked to the storage and preservation systems in West Africa

Alteration of the quality and quantity of stored corn is related to biochemical (chemical reactions within the grain) and biological (insects and other microorganisms) factors that cause severe losses at a time when the production system can hardly compensate for them. Each year, large quantities of crop products are spoiled or infested while in storage facilities before being delivered to consumers. In many Sub-Saharan African countries, storage and preservation infrastructures are poorly developed, and regular losses of maize can reach 40 to 50% after six (6) months of storage (**Adégbola 2010**). The degradation process of harvested products can be so rapid that the food becomes practically unfit for consumption in a few days. Among the pests that significantly affect stored maize are mainly insects, fungi and rodents.

Meteorological and biochemical factors
During storage, the living organisms that are the grains breathe. This activity causes a loss of dry matter, in this case starch, while producing carbon dioxide, water (in the form of steam) and heat. This phenomenon is frequently observed in wet stored grain masses. It gives rise to a strong variation of temperature, to the development of micro-organisms such as molds and finally to a mass setting of the grains. In addition to the metabolic activity of the grain, the heat, the moisture content of the grain and the harvest date influence the heat release.

Factors related to biological agents of degradation
The main biological agents responsible for grain spoilage during storage are insects, microorganisms and rodents.

Grain microorganisms: The microorganisms observed in grain storage consist of bacteria, yeasts and molds. The average lower limits of development according to the relative humidity of the air are 90% for bacteria, 85% for yeasts and 65% for molds. In general, it is therefore the molds (the genera Aspergillus and Penicillium) that are the most frequent threat during storage. During their development, they sometimes produce toxins that make the food on which they are present unfit for human or animal consumption. The best-known case is that of aflatoxin, a carcinogenic mycotoxin produced by Aspergillus favus.

Rodents: The main predatory rodents of stocks are the grey rat, the black rat and the mouse, which are found in almost all climates. Depending on the region, local rodent species may also attack stored products. Rodents cause quantitative losses by consuming the products and qualitative losses by soiling the food with their droppings. They also cause damage to storage structures or packaging (bags) (**lLü -**

WEP, 1986). To fight against these various factors of degradation of the grains several methods of control are used at the level of the country.

Insects: In the tropics, many species of insects attack stored foodstuffs. Some are specific to storage, while others can infest products in the field. The main insect pests of cereal products belong to two orders:

Beetles such as Sitophilus zeamaïs, Rhizopertadominica, Prostephanustruncatus, have membranous wings protected by "elytra". This makes them relatively resistant and allows them to move in a mass of grains.

Lepidoptera or butterflies such as Sitotrogacerealella, and Ephestiacautella have two pairs of fragile (scaly) wings and only infest the surface layer of grain masses (**Genest et al., 1990; Delobel and Tran, 1993; Traore et al., 1996**).

In stocks, insects cause important losses by consuming the albumen and sometimes the germ of the grains. It is often the larvae, for certain species living inside the grains, that cause the most sensitive damage. Finally, through their biological activity, which produces waste (fine flour), heat and water vapour, insects create a favourable environment for the development of micro-organisms (**ILü WEP, 1986**).

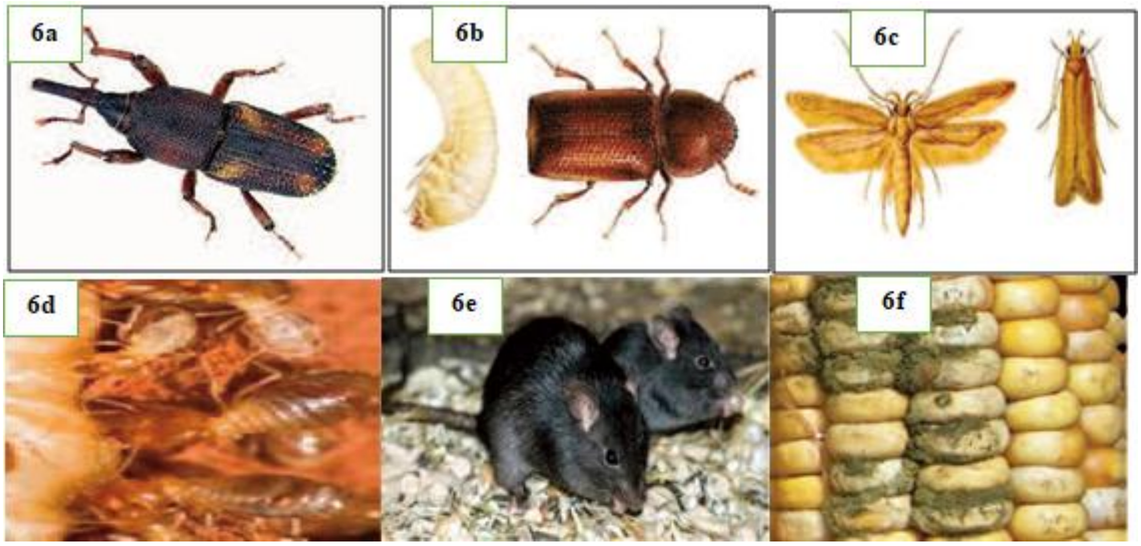

Figure 6: Major maize stock pests (HELVETAS, 2016): **6a**: Weevil (Sitophillus zeamaïs Motschuisky); **6b**: Beetle (Protéphanus truncatus); **6c**: Cereal alucites (Sitotrogaceréalella); **6d**: Termites; **6e**: Rodents (Rattus rattus (Rat), Mus musculus (Mouse)); **6f**: Molds (Aflatoxins)

4. Bonnes pratiques de stockage et de conservation du maïs (HELVETAS, 2016)

4.1 Good harvesting practices for corn

In Africa, maize cobs are harvested fresh or dry, depending on the variety, taste and use. The methods of harvesting dry maize are almost the same from one country to another.

Maize is harvested when the cobs are mature and the leaves and spathe are dry. Harvesting at the right time guarantees the quality of the grain and its by-products. This harvest is carried out according to good harvesting practices and the technology used for each production area.

The harvesting period corresponds to the maturity of the corn and can be recognized by the following

- The dried and cracked leaves with the corn cob still standing
- The spathes of the ears of corn are more than 75% of light-yellow color or bank and dried;
- The silks are reddish and can be removed easily;
- The corn kernels are hard and turn to the color of straw according to the varieties;
- The presence of the black layer that forms at the base of the kernel. This layer can be observed by removing the kernels from the cob and scraping the tip with a finger nail;
- The corn kernels scratch the nail;
- The corn grains broken with the teeth cause a dry noise;

The necessary arrangements (cleaning of tarpaulins, containers, bags, granaries) must be made at least two weeks beforehand for a good execution of the corn harvest.

Harvesting operations are carried out in sunny weather or not covered by clouds. The maize harvest is done manually as follows

- Cut the corn cob without spathe on the ground;
- Separate the healthy corn cobs from the attacked or infected cobs;
- Use bags or baskets to harvest the corn cobs;
- Immediately after harvesting, transport the filled bags or baskets from the field to the storage facility.

Corn harvested in spathe must be dispatched in the field. The method of storage determines the operations to be performed:

- Storage on the cob requires granaries made of plant materials or cribs to ensure the continued drying of the cobs;
- Grain storage requires prior drying on suitable drying areas (tarpaulin, black oilcloth or masonry) and

appropriate storage structures (improved closed earthen granary, metal drums, metal silos, PICS bags, etc.).

4.2 Good corn storage practices

- Make sure the attic, stores, bags, flut, silos... are in good condition;
- Clean the surroundings and burn the waste before storage;
- Check the presence of the anti-rat device which prevents access to the storage places;
- Treat the interior of the storage areas with registered and recommended insecticides or with biological products (neem leaves, cauliflower bark, etc.).

To put maize in storage, the following operations should be followed

- Spread the corn cobs in the sun on a clean drying area (clean tarp, cemented area, etc.) to reduce the moisture content to no more than 14%;
- Sort the cobs by eliminating those already attacked or bearing moldy kernels. Mouldy grains should be burned or buried, as they should not be consumed by humans or animals, as they could be contaminated with aflatoxin;
- Raise the part of the roof that covers the loft filling opening;
- Fill the granary from the top in successive layers of healthy corn cobs with a phytosanitary treatment for storage of more than 3 months. The treatment product can be a registered and recommended synthetic product or an organic product (neem leaves, caïlcedra bark, Hyptissuaveolens leaves, etc.);
- Close the open part of the roof after filling.

4.3 Follow-up of the stock

Monitoring during the storage period of the corn is a very important step to ensure the good condition of the stock. The following actions are essential:

- Regularly inspect the condition of the stockpile and the granary at least once every 15 days;
- Avoid placing elevated objects near or under the attic to prevent rodents from reaching the attic floor;
- Pay attention to any noises coming from inside the attic; this is a good indicator of pests in the stockpile.

4.4 Maintenance of storage facilities

Maintenance actions include doing the following:

- Make the area around the granary clean on a regular basis by weeding, sweeping and burning waste to reduce pest attacks on the stock;
- Repair the granary as needed when a wood or stem is broken.

5. Conclusion

The objective of this study was to inventory maize storage and preservation systems in West Africa; to expose the limitations of these storage systems, the difficulties encountered during preservation, but also to list good maize storage and preservation practices.

The conditions of storage and preservation determine the success of maize preservation. Maize can be subject to significant damage and loss during storage. Factors leading to maize spoilage are multiple and occur in different ways during the storage period. Proper storage requires the judicious implementation of a set of measures that can protect stored maize from pests or at least reduce their action. To this end, the use of good practices such as open storage structures (granaries), closed storage structures (drums and silos) and bags stored in standard warehouses can prevent or minimize pest attack. These good practices also contribute to facilitating the regularity of supply to families and to bringing added value to producers.

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