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Insects and fungi in stored maize in Angola

Laurinda Paim[1], Graça Barros[2], Ana Magro[2]*, Elsa Borges da Silva[2,3], António Mexia[2,4], Arlindo Lima[2]

[1]Ministério da Agricultura de Angola, Av. Comandante Gika 42, Largo António Jacinto Edifício B, 1257 Luanda, Angola, [2]Department of Sciences and Engineering of Biosystems (DCEB), Instituto Superior de Agronomia (ISA), University of Lisbon, Tapada da Ajuda, 1349-017 Lisboa, Portugal, [3]Forest Research Centre (CEF), Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Portugal, [4]Linking Landscape, Environment, Agriculture and Food (LEAF), Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Portugal.
*Corresponding author: anamagro@isa.ulisboa.pt
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Abstract

In underdeveloped countries in Asia and Africa, non-effective post-harvest technologies and sometimes ideal environmental conditions for development of pests like insects, fungi, rodents and birds, can lead to damage of both raw or processed foods. Losses can achieve considerable proportions in dried vegetables used as food products, particularly in underdeveloped countries where food security problems are a daily basis routine. The major goal of the present study was the identification of insects and fungi associated with maize under local storage conditions in the Angola provinces of de Benguela, Bié, Cuando Cubango, Cuanza sul, Huambo, Huíla, Luanda, Malange and Namibe. A wide range of storage methods for cereals were sampled, from small containers of peasants and small farmers up to the large metal containers used by large agricultural companies and Estates. The achieved results will contribute for food security improvement in Angola and for the maintenance and preservation of good and healthy seeds at the traditional farmers' community level. The insect pests registered from the studied samples were *Cryptolestes ferrugineus, Gnatocerus maxillosus, Liposcelis bostrychophila, Oryzaephilus surinamensis, Rhyzopertha dominica, Sitophilus zeamais, Sitotroga cerealella and Tribolium castaneum*. The species *Prostephanus truncatus* was not found in the studied samples. Fungi in the genus *Aspergillus*, *Fusarium* and *Penicillium* were presented at a high incidence in all samples studied, although the relative abundance of different fungi species varied with the sample location.

Keywords: maize, insects, fungi, Angola, storage.

Introduction

In Angola, maize is the cereal with the highest production and one of the most consumed. An average maize yield of 640 kg/ha was reported for the period 2000-2010 (FAOSTAT, 2012). Although grain production in the country has increased, Angola still has a deficit of 3 million tons, achieving only 40% of consumption needs (INCER, 2014). Factors such as severe technical knowledge gaps, lack of incentives to producers, low fertility of soils, use of low-yielding varieties, non-application of technologies or lack of access to them, lack of access to production factors, lack of infrastructure for water management, lack of reliable storage structures, and low availability of credit resources greatly reduce the expected yields (Pacheco et al., 2011). There are a number of warehouse systems and warehouse types in Angola at the smallholder level. These warehouses are built with clay, sticks and covered with grasses or wood and grass. The poor condition of the warehouse structure, its hygiene and moisture control issues at the level of the small producer does not guarantee good phytosanitary status for the stored products.

Cereals storage is a specific agro-ecosystem, conditioned by several factors which are difficult to control, like temperature, relative humidity, water content, and oxygen availability (Barros, 1993). This is especially true in underdeveloped countries where technological innovations such as refrigeration and controlled atmospheres represent huge investments. Storage under deficient conditions can lead to insect or fungi attack, inducing organoleptic changes (taste, flavour and appearance), nutritional losses or even mycotoxin contamination. These cause significant economic losses and can represent serious health problems.

The insects of stored grains have certain preferences regarding temperature, relative humidity, water content and food. The interaction of these factors affect, directly or indirectly, the insects' proliferation rate and thus the possibility of causing damage and/or loss during storage of those products (Barros, 1996).

The objective of this work was to identify species of insect and fungi responsible for the deterioration of stored cereals present in samples of maize from Angola, and as a result contribute in some way to the improvement of the storage conditions of these products. Aim was not only to confirm the storage pests already identified in Angola in previous studies, but also to check for the presence of *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae). This species is a pest of stored maize and cassava, which became a major concern after being accidentally introduced in Africa.

This is pioneering and very important work for Angola. It covers approximately 50 % of the national territory evaluating the phytosanitary situation of stored cereals in the Benguela, Bié, Cuando Cubango, Cuanza Sul, Huambo, Huíla, Luanda, Malange and Namibe provinces, identifying all the insects and fungi present in the studied cereal samples.

Materials and Methods

Maize samples were collected randomly in Angola in different quantities and packed in plastic or paper bags, and transported to the laboratory in Lisbon. The samples were kept cool (0-4°C) after collection, during shipping and at the laboratry until being observed. These procedures took 7-8 days.

Samples originated from different sources, from small producers in the provinces of Benguela, Bié, Cuando Cubango, Huambo and Huíla, from the business sector, from the Pungo Andongo farm in the province of Malange and from the local markets of the provinces of Cuanza Sul, Luanda and Namibe. At the arrival of the samples in the laboratory they were cleaned and sieved for removal of stones, dust, crop pieces, excrement and insects. Then, using the Boerner divider the samples were subdivided for later entomological and mycological analyzes.

Insects analysis

The insects present in the maize samples, on arrival, were identified and recorded. The maize samples were then placed in glass bottles, identified with origin, arrival date and incubated at 27±1°C and 75-80 % relative humidity. The purpose of this procedure was to observe and identify the emergence of hidden adult insects inside the maize kernels.

Mycoflora analysis

Maize samples from six provinces of Angola were collected in sterilized containers and taken into the ISA laboratory. The maize samples were sub-divided into 110 kernel samples. These sub-samples were surface disinfected with 1 % sodium hypochlorite for two minutes, as describe by Pitt and Hocking (1997) and Magro et al. (2006).

Ten dried grains were placed in Petri dishes with 20 mL of Potato Dextrose Agar (PDA) medium with chloranphenicol (1 %). For each sample, ten replicates were made. Petri dishes with grains were incubated at 25°C for 7 days and then examined under a light stereomicroscope for fungal growth. Isolation of the colonies was made to obtain pure cultures. Slides of fungal growth were prepared and observed under a compound microscope for fungal morphology study. Identification was carried out using identification keys (Carmichael et al., 1980; Domsch et al., 1980; Onions et al., 1981; International Mycological Institute, 1991; Hanlin, 1997; Malloch, 1997; Pitt & Hocking, 1997; Barnett & Hunter, 1998; Samson et al., 2004).

Results

Insects

Table 1 shows a list of the insects identified in the maize samples from eight provinces of Angola. It was found that *C. ferrugineus*, *S. zeamais* and *S. cerealella* were present in all samples.

Tab. 1 Identified insects in stored maize samples from eight provinces of Angola.

Insect	Province							
	Benguela	**Bié**	**Cuanza Sul**	**Huambo**	**Huíla**	**Luanda**	**Malange**	**Namibe**
COLEOPTERA								
Cryptolestes ferrugineus	+	+	+	+	+	+	+	+
Gnatocerus maxillosus	+	+	-	-	-	-	-	-
Oryzaephillus surinamensis	-	-	+	-	-	+	+	-
Rhyzopertha dominica	+	+	-	+	+	-	+	+
Sitophilus zeamais	+	+	+	+	+	+	+	+
Tribolium castaneum	+	+	+	+	+	+	-	+
LEPIDOPTERA								
Sitotroga cerealella	+	+	+	+	+	+	+	+
PSOCOPTERA								
Liposcelis bostrychophila	-	-	+	-	-	+	+	+

Note: (-) without insects and (+) with insects.

Fungi

In this study, field and storage fungi were detected and identified in all samples. The field species isolated were *Diplodia maydis*, *Nigrospora* sp., *Rhizopus* sp., *Trichoderma* sp. and *Trichothecium roseum*.

The storage species isolated were *Aspergillus candidus*, *A. clavatus*, *A. flavus*, *A. fumigatus*, *A. niger*, *A. ochraceus*, *A. parasiticus*, *A. wentii*, *Fusarium moniliforme*, *F. oxysporium*, *Penicillium citrinum*, *P. funiculosum*, *P. furcatum*, *P. islandicum*, *P. purpurogenum*, *P. variabile* and *P. pinophilum*. The presence of different taxa in samples from the six provinces is presented in the Table 2.

Tab. 2. Frequency of identified fungi in stored maize samples from six provinces of Angola.

	Province					
	Benguela	**Bié**	**Huambo**	**Huíla**	**Malange**	**Namíbe**
High frequen-cy	*Fusarium moniliforme* *P. citrinum*	*A. clavatus* *A. flavus* *A. ochraceus*		*F. moniliforme*	*A. flavus*	*Trichothecium roseum*
Frequent	*Rhizopus sp.*	*P. funiculosum*	*A. flavus* *A. fumigatus* *A. ochraceus* *F. moniliforme* *P. variabile* *P. pinophilum*	*A. flavus* *A. parasiticus* *P. purpurogenum*		*A. flavus* *P. citrinum* *P. variabile*
Low frequency	*A. clavatus* *A. flavus* *F. oxysporum* *P. islandicum*	*A. niger* *A. parasiticus* *F. moniliforme* *Nigrospora* sp. *P. pinophilum*	*A. niger* *A. parasiticus* *P. citrinum* *Trichoderma* sp.	*A. candidus* *A. niger* *A. wentii* *Diplodia maydis* *P. funiculosum* *P. furcatum*	*P. funiculosum* *P. furcatum*	*A. candidus* *A. niger* *F. moniliforme* *P. funiculosum* *Rhizopus* sp.

P. pinophilum
Rhizopus sp.

Discussion

The results show that most of the insects present in the studied samples belong to the Coleoptera order, confirming the results obtained by Amaro & Gouveia (1957), Carvalho (1984) and Matos (2004). Data support the conclusion of no differences in species in relation to the sample collection site; i.e., insect species found in samples collected in the silos are the same as those obtained in the local market.

The presence of the same insect species that have been identified in the other provinces is highlighted in Malange, which is somewhat worrisome given that the maize sample from this province belongs to a major agricultural company, which theoretically has good technical advice and practices, while the other samples are from small local producers and markets.

In all of the provinces where maize samples were collected the presence of *P. truncatus* was not detected. It is of paramount importance to continue this work by collecting a larger number of samples, for each province, for each type of storage, in maize, from the small farmer to the large storage companies, to detect the arrival of *P. truncatus*, a devastating pest already present in many African countries. Ensuring continuous training and implementation of pesticide regulation are also a priority for Angola.

Field fungi colonize maize grains only when the water activity (aw), temperature and relative humidity are high. However, as a result of an adaptation to low aw, fungi belonging to *Aspergillus* spp., and *Penicillium* spp., also designated as storage fungi, are able to invade the maize grains stored at aw levels considered as safe. They are frequently responsible for causing serious losses, even before they were visually detected. They affect negatively the product's appearance, flavour, odour and nutritional content. They also may produce mycotoxins with large impact on public health (Magro, 2001). It is important to emphasize that *Aspergillus* spp., *Fusarium* spp. and *Penicillium* spp., are potential mycotoxins producers. It is fundamental to improve and control the maize storage conditions as well as the cleaning process before any further grain processing.

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Automated detection and monitoring of grain beetles using a "smart" pitfall trap

Panagiotis A. Eliopoulos*[1], Ilyas Potamitis[2], Iraklis Rigakis[3]

[1]Technological Educational Institute of Thessaly, Department of Agriculture Technologists, 41110 Larissa, Greece, eliopoulos@teilar.gr.
[2]Technological Educational Institute of Crete, Department of Music Technology and Acoustics, 74100 Rethymno, Greece, potamitis@staff.teicrete.gr
[3]Technological Educational Institute of Crete, Department of Electronics, 73133 Chania, Greece, iraklis.rigakis@gmail.com
*Corresponding author: eliopoulos@teilar.gr
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Abstract

A smart, electronic, modified pitfall trap, for automatic detection of adult beetle pests inside the grain mass is presented. The whole system is equipped with optoelectronic sensors to guard the entrance of the trap in order to detect, time-stamp, and GPS tag the incoming insect. Insect counts as well as environmental parameters that correlate with insect's population development are wirelessly transmitted to a central monitoring agency in real time, are visualized and streamed to statistical methods to assist effective control of grain pests. The prototype trap was put in a large plastic barrel (120lt) with 80kg maize. Adult beetles of various species were collected from laboratory rearings and transferred to the experimental barrel. Caught beetle adults were checked and counted after 24h and were compared with the counts from the electronic system. Results from the evaluation procedure showed that our system is very accurate, reaching 98-99% accuracy on automatic counts compared with real detected numbers of adult beetles inside the trap. In this work we emphasize on how the traps can be self-organized in networks that collectively report data at local, regional, country, continental, and global scales using the emerging technology of the Internet of Things (IoT). We argue that smart traps communicating through IoT to report in real-time the level of the pest population from the grain mass straight to a human controlled agency can, in the very near future, have a profound impact on the decision making process in stored grain protection.

Keywords: pitfall trap, sensors, Internet of Things, stored grain, beetle pests.

Introduction

Low tolerance of the presence of insect pests in stored grain requires the development and implementation of detection and monitoring methods that are sensitive enough to detect early pest infestation to prevent quality and economic losses (Trematerra, 2013). Today, the innovative uses of sensors and networks targeting animals are starting to be translated into new ecological knowledge (Portet et al., 2009). Traps equipped with a detection sensor and wireless communication abilities have some distinct advantages against manual monitoring. They can monitor insect populations 24 h a day, upon their entrance to the trap, every day of the year, in dispersed nodes across a variety of fields, simultaneously, and all counts and recordings can be permanently stored in a cloud service. Another distinct advantage is the determination of the precise onset of an infestation. Real-time reporting, opens new grounds in stored product research and mainly in crop protection as – besides a timely control action in response to a pest infestation – it can help in the evaluation of the impact of a control treatment and therefore reschedule future actions if necessary.