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Commercial Yam Tuber (*Dioscorea spp.*) Handling during the Harvest and Post-Harvest Storage

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Abstract

Context: Yam losses at harvest and storage can be significant if proper management is not implemented.
Aim: This research aimed to reduce the losses of commercial yam tubers (*Dioscorea spp*.) through proper harvest and post-harvest storage handling.
Methods: The incidence of the main pests and diseases on commercial yam tubers (*Dioscorea spp.*) during the harvest, along with its response at post-harvest storage at room temperature under indirect sunlight, in a clean and aerated facility, in loophole bags. At 0, 30, and 60 days of storage, the morphological and agronomical parameters were determined. A survey was applied to analyze the organoleptic traits of commercial yam tubers at 0 and 60 days of storage.
Results: The main diseases observed in commercial yam tubers at harvest were *Botryodiplodia theobromae*, *Penicillium spp.*, and *Aspergillus flavus*, *Link*. All the clones evaluated showed that when the storage time reached 60 days, the fresh mass percentage was reduced, whereas there was an increase in the dry mass percentage. The storage of commercial yam tubers *D. alata*, clones *Criollo*, *Chino Blanco*, *Caballo*, *Caraqueño*, and *D. esculenta*, clone *Papa* was made successfully in loophole bags for up to 60 days in an aerated, clean facility with indirect sunlight, at room temperature. The organoleptic tests showed that clone *Chino Blanco* was the most favored one by the panelists.
Conclusions: A plan was for *Dioscorea spp.* tuber handling during the harvest and post-harvest storage was designed.

Keywords: sustainable agriculture, conservation, diseases, pests, organoleptic tests.

Introduction

Yam belongs to the genus *Dioscorea*, with more than 600 species, though only six of them have nutritional and economic relevance worldwide (Abasimi, 2018).

Yams are dioic, monocot angiosperm plants characterized by the production of underground tubers (Rodríguez, Rodríguez, Milián, Arce & Figueroa, 2017)

According to FAOSTAT (2018), in 2017, Africa is the largest yam producer, with almost 97% of production (70.9 million tons). In contrast, the Americas represented 2.0% of the global production (1.4 million tons).

Yam is only second to potato in terms of efficiency to produce digestible energy, so it is considered a highly significant crop for food safety in tropical countries. Likewise, starch production has been established as a raw material for cosmetics, processed foods, bioplastics, and biofuels (Maya 2015). However, the production and sale of yam internationally are based on the fresh product, the most commonly demanded category in the international market (Vargas, 2019)

Yam (*Dioscorea spp.*) is a tuber planted by small farmers in tropical areas (Andres, Adeoluwa & Bhullar, 2017). It has a high nutritional value (Akinrinola & Adeyemo, 2018; Raphiou, Siaka, Kouami, Nebambi & Bello, 2019), and it is a significant source of energy in the human diet (Quainoo, Addai, Damba & Opoku, 2015).

To small farmers, yam production is an important source of food and income, and it plays a critical role in their sociocultural lives (Iddi, Donkoh, Danso-Abbeam, Kart & Akoto-Danso, 2018).

Yam is highly nutritional and is part of the orphan crops, which the United Nations Organization for Food and Agriculture (FAO) is promoting to fight world hunger (Swisslatin, 2016).

The post-harvest stage begins with the harvest in the fields and ends in the kitchen of consumers. For research purposes, it comprised factors like storage and transport temperature, packing, and handling (López, 2016).

Several pests and diseases attacking yam remain from season to season thanks to the utilization of infected material. The development of a system to generate healthy material cuts this cycle of the disease and reduces the field losses during post-harvest storage (Claudius-Cole Kenyon & Coyne, 2017).

There have been regulations to develop the post-harvest sector in agriculture due to the losses created by crops like yam (Ayado, 2017). The post-harvest losses have called the attention of many nations to ensure world food safety, particularly in developing countries (Ansah & Tetth, 2016).

The causes of yam storage-related losses include shooting, transpiring, breathing, rotting resulting from bacterial contamination, and the attack of insects, nematodes, and rodents. Shooting, transpiring, and breathing are physiological activities that depend on the storing environment (especially temperature and relative humidity). These physiological changes affect the internal composition of the tuber and destroy the plant material and cause poor nutritional quality.

The storage-related losses reported for yam are 10-15% after the first three months and may approach 50% after six months (Adejo, 2017).

In Cuba, the literature reviewed has not reported on research related to the loss of commercial yam tubers (*Dioscorea spp.*) so far during the harvest and post-harvest storage. This research aimed to reduce the losses of commercial yam tubers (*Dioscorea spp.*) through proper harvest and post-harvest storage handling.

Materials and methods

The study was conducted at the Center for Plant Biotechnology Studies (CEBVEG), the University of Granma, in the municipality of Bayamo, province of Granma, Cuba.

Plant material

Commercial yam tubers (*Dioscorea spp.*) were used from the seed bank at CEBVEG harvested at 9 months. The harvest was manual, nine months after plantation, using a pick, hoe, and spade to prevent the crop from damaging. The tubers were stored in bags (loophole) and hung at room temperature in an aired facility with indirect sunlight.

Commercial yam tuber (*Dioscorea spp.*) handling during the harvest and post-harvest storage

The purpose of the experiment was to evaluate the losses of commercial yam tubers (*Dioscorea spp.*) during the harvest.

A completely randomized experimental design was applied. The treatments consisted of the utilization of *Dioscorea spp.* clones. (Table 1). Of a population of 100 commercial tubers per treatment, 30 tubers were studied in three repetitions.

Table 1. Treatment obtained during the harvest of commercial yam tubers (*Dioscorea spp.*)

Treatments	Clone
1	*D. alata* (Criollo blanco)
2	*D. alata* (Caballo)
3	*D. alata* (Caraqueño)
4	*D. alata* (Chino blanco)
5	*D. esculenta* (Papa)

The following parameters were evaluated at harvest:

Loss percentage: mechanical damage, and pests and diseases.

Identification of the main pests according to the Technical Manual for Yam (MINAG, 2008).

Identification of pathogenic organisms

This process was based on the Normative Operational Protocols for Phytosanitary Inspection (FAO, 2011) adjusted to the laboratory conditions.

An incision was made to the tubers affected by fungi, which compromised the symptom and the non-infected areas nearby. These tissue fragments were placed in a humid chamber under aseptic conditions for 24 hours. Samples were taken from the germinated mycelium, and they were observed through the optic microscope to identify the agent causing the symptoms. The results were compared using the CMI (1976) key to corroborate the results.

Commercial yam tuber (*Dioscorea spp.*) handling during the post-harvest storage at room temperature under indirect sunlight, in a clean and aerated facility, in loophole bags

The purpose of the experiment was to evaluate the response of commercial yam tubers (*Dioscorea spp.*) during the post-harvest storage until 60 days.

A completely randomized experimental design was implemented. The treatments consisted of the utilization of *Dioscorea spp.* clones at three different times of storage (0, 30, and 60 days). (Table 2.) Of a population of 100 commercial tubers per treatment, 30 tubers were studied in three repetitions, at random.

Table 2. The treatments (T) were obtained during the harvest of commercial yam tubers (*Dioscorea spp.*) at 0, 30, and 60 days, at room temperature

T	Clone	Storage time (days)
1	Criollo Blanco	0
2	Criollo Blanco	30
3	Criollo Blanco	60
4	Caballo	0
5	Caballo	30
6	Caballo	60
7	Caraqueño	0
8	Caraqueño	30
9	Caraqueño	60
10	Chino Blanco	0
11	Chino Blanco	30
12	Chino Blanco	60
13	Papa	0
14	Papa	30
15	Papa	60

The values recorded by the climatic variables during the experiments were temperature (30±2°C); relative humidity (70-80%); and photoperiod (12-14 light hours).

Evaluations

At 0, 30, and 60 days of storage, the following parameters were determined:

Morphological parameters

Color and shape

Shooting percentage

Shoot diameter (cm) was measured using a gauge caliper, at 30 and 60 days the shoot diameter.

The shoot length (cm) was measured using a measuring ruler at 30 and 60 days.

Agronomic parameters

Loss percentage: mechanical damage, pests and diseases, harvest, and post-harvest.

The fresh tuber mass (kg) was determined using a technical balance.

The dry mass percentage was determined using the gravimetric method, by placing 10g of the tuber on a stove at 700C for 72 hours until a constant mass was achieved; then it was weighed in a single plate digital electric balance (11-DO629) with a 0.3 mg precision.

Identification of the main pests and diseases according to the Technical Manual for Yam (MINAG, 2008), and the Guide for the Regeneration of Yam Germplasm (Dumet & Ogunsola, 2008).

Organoleptic tests

An organoleptic analysis of the commercial yam tubers (*Dioscorea spp.*) was performed through a survey of 30 individuals after tasting different dishes containing boiled yam chunks, at random. A dish of mashed yam was prepared, and a seasoning made of garlic, salt, sunflower oil, vinegar, and lemon juice was added.

Opinions evaluated

Dish X

Taste: __Excellent __Good __Average __Bad

Looks: __Excellent __Good __Average __Bad

Texture: __Hard __Semi-hard __Soft

The desire to eat it again.

__Always __Sometimes __Never

Key (the yam clone corresponding to each dish was chosen at random).

Dish 1. *Criollo* clone.

Dish 2. *Caballo* clone.

Dish 3. *Caraqueno* clone.

Dish 4. *Chino blanco* clone.

Dish 5. *Papa* clone.

Loss reduction through the handling of commercial yam tubers (Dioscorea spp.) during the harvest and post-harvest storage

A set of measures was designed to prevent losses through proper handling of commercial yam tubers of *Dioscorea spp.* during the harvest and post-harvest storage based on the positive results from previous experiments.

Statistical analysis

A simple analysis of variance was used together with Tukey's multiple mean comparison test, with a 5% error probability. The Kolmogorov – Smirnov test was performed to check data normality, and the Barttlet test was run to check variance homogeneity. All the statistical analyses were run using the software Statistica for Windows, 10.0 (StatSoft, 2011).

Results and discussion

Commercial yam tuber (*Dioscorea spp.*) handling during the harvest

Harvest-related losses.

Nine months following leaf senescence, and after the tubers turned dark brown in the distal area, the harvest was performed carefully to reduce tuber damage. Cleaning was done before transportation and storing.

In that sense, Quiros et al., (2007) noted that normally, the yam harvest is performed between nine and ten months following the sowing. Harvest takes place when the leaves turn yellow and fade, and the tubers' distal area is coffee brown. The work must be careful and slow to prevent tuber damage. Initially, the field guides are removed, and the tops are cut to facilitate the harvest.

The previous authors said that when the tubers are selected according to the packing plant requirements, the product is carried to the plant for washing, preselection, washing, drying, and placing in the plant's yard for packing in newspapers individually. when the box is filled, the tubers are transported in pallets to the container. Generally, yams are exported fresh or consumed nationally, also fresh.

This study found that there were losses during the harvest (Table 3) varying between 14 and 17%, as a result of mechanical damage to tubers during the harvest, originated from cuts and bruises when uplifting, piling, gathering and transporting.

Similar results were reported by Adejo (2017), who demonstrated that most losses from harvest through the first 90 days of storage ranged between 10 and 15%, caused by factors like pests, diseases from fungi and bacteria, poor handling and logistics, inappropriate storing capacities, and mechanical damage.

Table 3. Losses due to mechanical damages when harvesting commercial yam tubers (*Dioscorea spp.*)

Treatments	Loss percentage by mechanical damage
D. alata (Criollo blanco)	15
D. alata (Caballo)	14
D. alata (Caraqueño)	16
D. alata (Chino blanco)	17
D. esculenta (Papa)	14
SE	0.43

SE=standard error

Moreover, Coursey (1967) said that different from grains, every tropical root plant or tuber is part of fragile and short-lived foods. The harvest is delicate and must be performed with care, as it conditions all the subsequent operations, especially any action to prevent damage or losses.

The study did not identify bacteria but did identify fungi *Botryodiplodia theobromae* and *Penicillium spp.* (Table 4, Figure 1) in the Papa and Caballo clones, from the dry rotting seen in them. Meanwhile, in the Criollo and Caraqueno clones, fungi *Penicillium spp.* and *Aspergillus flavus*, Link. were found. The results were compared using the CMI (1976) key.

The presence of diseases is mainly due to mechanical damage during the harvest since these fungi are capable of penetrating through the damaged epidermis and affecting the tuber.

In that sense, Dumet & Ogunsola (2008) claimed that the main disease observed in the crop's harvest is the rotting of the tuber, which is caused by different types of fungi. Among them is soft rotting caused by *Penicillium spp.*, *Fusarium oxysporum*, and *Botrydiplodia theobromae*, and dry rotting caused by *Rosselinia* and *Sphaerostilbe*. Other fungi found frequently were *Rhizopus nodosus* and *F. solani*.

Table 4. Identification of the effect of the main diseases of commercial yam tubers (*Dioscorea spp.*) during the harvest

Clone	Pests identified
Papa	*Botryodiplodia theobromae* *Penicillium spp.*
Caballo	*Botryodiplodia theobromae* *Penicillium spp.*
Caraqueño	*Penicillium spp.* *Aspergillus flavus* Link.
Chino Blanco	
Criollo	*Penicillium spp.* *Aspergillus flavus* Link.

The rotting of yam tubers is originated in the field and they progress during storage. There may be dry rotting (causing mild spots and weakening of the plant), humid rotting (disintegrating the tissue into a watery mass), and heavy rotting (causing total tissue maceration). Several microorganisms causing the rotting of the tuber have been identified (*Sclerotium rolfsii, Botryodiplodia theobromae, Penicillium* spp., *Rhizopus* spp., *Fusarium* spp.) (MINAG, 2008).

The traditional storing facilities have reported losses of over 25%. The rotting caused by fungi and bacteria (many of them pathogenic) has originated a large share of the losses during storage.

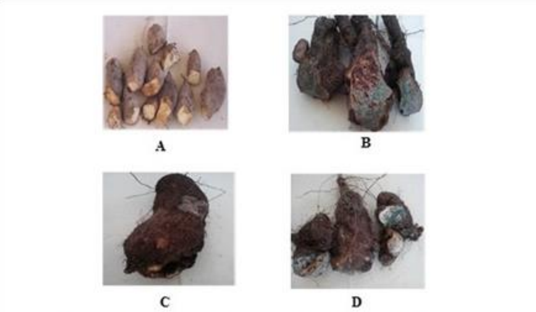

Fig. 1. Presence (*Dioscorea spp.*) of *Botryodiploidia Theobromae*, and *Penicillium spp.* in commercial yam tubers: Clones *Papa* (A) and *Caballo* (B); *Penicillium spp.* and *Aspergillus flavus* Link. Clones *Caraqueno* (C) and *Criollo* (D).

Commercial yam tuber (*Dioscorea spp.*) handling during the post-harvest storage at room temperature under indirect sunlight, in a clean and aerated facility, in loophole bags

The post-harvest storage of commercial tubers included the removal of every sick or damaged tuber by tools; then the healthy tubers were stored in an aerated and clean facility, under indirect sunlight. This procedure coincided with the reports of MINAG (2008), which refer that proper storage must be based on the total removal of all the sick tubers or tubers damaged by the harvesting tools. They must be placed in the shade, though weight loss is inevitable, which for *D. alata* may vary between 8 and 23%, depending on the clone stored.

Moreover, FAO (1985) pointed out that the yam tuber condition must be observed when being stored to determine its duration. Only the healthy yams must be stored; that is, the nematode-free, unrotten yams, and yams without any physical damage. To reduce the physical lesions, it is necessary to handle the tubers carefully throughout the entire collection and transport process. Each lesion, scratch or bruise, or deep cut produced with a machete or hoe used to dig the crop out will make it more susceptible to the attack of pathogens and further rotting during the storage process. Tuber exposure to intense sunlight for a long time should be avoided, especially the freshly dug out tubers, as it may cause lesions and lead to rotting.

Morphological parameters

The color of different yam clones (*Dioscorea spp.*) at 0, 30, and 60 days, at room temperature, under indirect sunlight, in a clean and aerated facility, in loophole bags. The color varied between dark brown and light brown in clones *Criollo blanco*, *Caballo*, and *Chino blanco*, and clone *Caraqueño* varied from light brown to mild brown, while clone *Papa* did not undergo a color change, remaining light brown.

Additionally, several tuber shapes were observed in various clones of yam (*Dioscorea spp.*): oblong (*Criollo blanco*); elongated and flat (*Caballo*); irregular (*Caraqueño*); ovate (*Chino blanco*); and elliptical (*Papa*).

In that sense, Jiménez & Hernández (2009) pointed out that the morphological description of the vegetative and reproductive organs, as well as the classic agronomic traits, have been very helpful for the characterization and evaluation of the genetic resources. These descriptors may be defined as attributes that can be observed in the plant, and be easily quantified and identified, allowing for quick phenotype discrimination.

These results were compared to the findings of Leyva (2017), who evaluated the seed bank classified at the Center for Plant Biotechnology, the University of Granma, with a morpho agronomic perspective. They also matched the descriptors of IPGRI/IITA (1997) and Aguilar (2012), which offer a morphological and molecular characterization of Dioscorea spp. at the Germplasm Bank of the Tropical Agronomic Center for Research and Teaching (CATIE), Costa Rica.

Furthermore, the storage characteristics are different for the various yam species. Generally, the water yam (*Dioscorea alata*) is better conserved than the white yam (*D. rotundata*), and the latter is, in turn, better than the yellow yam (*D. cayenensis*). There are also differences among the varieties of the same species. Clones with better storage features have longer latency periods, which heal well, and the ones with shapes facilitate digging them out without lesions. The clones with poor storage attributes should be consumed or sold first, and the clones with the best storing attributes should be conserved.

Shooting percentage

At 60 days, the shooting percentage was significantly higher (p<0.05) in the *Papa* and *Chino blanco* clones, with 80 and 76% shooting, followed by the *Caraqueno* (63.3%), and *Criollo* (53.3%). These results were similar to the ones reported by (2017) 30 days after field establishment, with 82.0% shooting in the treatments with the *D. alata* species, clone *Caraqueno*, and 87.5% for the *Chino blanco* clone. However, they did not match with the higher values found for clone *Criollo*, (87.4%), clone *Caballo* (99.0%), and *D. esculenta* clone *Papa* (38%).

Shoot diameter and length

The shooting diameter and length are shown in Table 5. The highest value was observed in clone *Chino blanco* (0.76 cm diameter, and 14.82 cm length), whereas the lowest results were found in clone *Papa* (0.42 cm and 1.28 cm, respectively).

Table 5. Shoot diameter and length of different commercial yam clones (*Dioscorea spp.*) at 60 days of storage

Clones	Shoot diameter (cm)	Shoot length (cm)
Criollo	0.58 b	1 d
Caballo	0 e	0 e
Caraqueño	0.55 c	3.40 b
Chino Blanco	0.76 a	14.82 a
Papa	0.42 d	1.28 c
SE	0.03	1.43

The means with different scripts differed significantly for p<0.05, Tukey's test. SE=standard error.

Similar results were reported by Leyva (2017) about the diameter of clones *Criollo* and *Caraqueno* (0.60, 0.61, respectively), and much less for clone *Papa* (0.14 cm). The difference observed for *Papa* results from a species trait, whose architecture has very thin stems.

Agronomic parameters

Fresh tube mass

Table 6 shows the fresh tuber mass (FTM) of different yam clones (*Dioscorea spp.*) at different storage moments. At 0 days, it was between 1.1 and 0.10 kg, averaging 0.66 kg. The most significant values (p<0.05) were found in *Papa*, *Chino blanco*, and *Caraqueno* (1.1, 0,90 y 0.66 kg, respectively), followed by *Criollo* and *Papa* (0.45 and 0.10 kg). At 30 days, it was between 0.82 and 0.08 kg, with an average value of 0.52 kg; the *Chino blanco*, *Caballo*, and *Caraqueno* stood out among them (0.82, 0.72, and 0.52 kg, respectively), followed by *Criollo* and *Papa* (0.43, 0.08 kg, respectively). At 60 days of storage, it was between 0.80 and 0.07 kg, with an average value of 0.47 kg; the *Chino blanco*, *Caballo*, and *Caraqueno* stood out among them (0.80, 0.70, and 0.47 kg, respectively).

Table 6. Fresh tuber mass (kg) from different commercial yam clones (Dioscorea spp.) at different times of storage and at room temperature (RT)

Clones	Shoot diameter (cm)	Shoot length (cm)
Criollo	0.58 b	1 d
Caballo	0 e	0 e
Caraqueño	0.55 c	3.40 b
Chino Blanco	0.76 a	14.82 a
Papa	0.42 d	1.28 c
SE	0.03	1.43

CB *Criollo blanco*, ChB *Chino blanco*, C *Caballo*, Cq *Caraqueno*, Pa *Papa*. The means with different scripts in the rows differed significantly for p<0.05, Tukey's test. SE=standard error.

All the clones studied evidenced that as storage time passed, the fresh tuber mass diminished, which might have been caused by the loss of water during this period, which varied between 18 and 26%. These results were corroborated by the findings of Osunde (2003) when evaluating different *D. alata* clones, where the loss of fresh mass varied between 19 and 22%. Similar results in *D. alata* were reported by MINAG (2008) (8-23%), depending on the clone stored.

Dry tuber mass percentage

The dry mass content (%) of different yam clones (*Dioscorea spp.*) at different storage moments is shown in Table 7. At 0 days, it was between 29 and 22 kg. *Caballo* and *Papa* reached the greatest significant percentages (29 and 25%, respectively), followed by the rest. At 30 days, it was between 30 and 23%; *Caballo* and *Papa* reached the greatest significant percentages (30 and 27%, respectively), followed by the rest. Obviously, at 60 days, it was between 31 and 24%, with the highest values in *Caballo*, *Papa*, and *Chino blanco* (31, 28, and 25%), followed by *Caraqueno* and *Criollo* (24%).

To summarize, the lesser the fresh tuber mass, the greater dry matter content, which may have occurred thanks to water loss during tuber storage, influencing their quality.

Table 7. Dry tuber mass percentage of different yam clones (*Dioscorea spp.*) at different times of storage and at room temperature (RT)

TA (days)	CB	ChB	C	Cq	Pa
0 days	22 c	23.3 c	29 a	22.3 c	25 b
30 days	23 c	24 c	30 a	23 c	27 b
60 days	24 c	25 c	31 a	24 c	28 b
SE	0.5	0.5	0.5	0.5	0.8

CB *Criollo blanco*, ChB *Chino blanco*, C *Caballo*, Cq *Caraqueno*, Pa *Papa*. The means with different scripts in the rows differed significantly for $p<0.05$, Tukey's test. SE=standard error.

These results were compared to the findings of Lebot (2009) when he offered a physicochemical characterization of yam tubers (Dioscorea spp.) which contained 13.68-37.4% dry matter.

Identification of the main pests and diseases

At post-harvest storage, the commercial yam tubers (Dioscorea spp.) at room temperature, did not show any signs of pest and disease incidence until 60 days, demonstrating that the storage method was appropriate to maintain the quality parameters of commercial yam tubers.

Organoleptic tests

The results of the organoleptic tests to the boiled mashed tubers with garlic seasoning in different commercial yam clones (*Dioscorea spp.*) at 0 and 60 days to evaluate the taste, showed that *Chino blanco* had the best flavor at 0 days (90% excellent and 10% goo), followed by *Criollo* and *Papa* (70% excellent), then *Caraqueno* (70% good), and *Caballo* (90% average). However, at 60 days, the panelists chose *Chino blanco* (70% excellent), followed by *Papa* (50%), *Caraqueno* (40%), and *Caballo* (40%).

Similar findings were reported by Hidalgo (2014) when characterizing the nutritional quality of yam tubers (*Dioscorea spp.*), using different analysis techniques, where the best values were observed in *Chino blanco* (70% excellent, 30% good), followed by *Criollo* and *Papa* (80% and 60% good, respectively).

The texture of the boiled tubers from different clones (*Dioscorea spp.*) at 0 and 60 days that *Chino blanco* had the best texture (semi-had), expressed by 100% of the panelists, followed by *Papa* (80%), *Caballo* (30%), and *Criollo* (20%). With a soft texture, *Caraqueno* (100%), and a hard texture, *Criollo* (80%), and *Caballo* (70%).

Hidalgo (2014) demonstrated 100% semi-hard texture of *Chino blanco* followed by *Caballo* and *Criollo* with a hard texture (60% and 90%, respectively). However, *Caraqueno* reached 80% in the soft category.

Likewise, the desire of the panelists to consume the boiled and mashed tuber of different clones (*Dioscorea spp.*) showed that at 0 and 60 days, *Chino blanco* had the highest acceptance, with 100% desiring to eat it again forever. Then clones *Papa*, *Caraqueno*, and *Criollo* (80%), and lastly, *Caballo* with 80% of the panelist reporting not to desire to consume it again.

In that sense, Poot–Matu & Cortes (2000) referred that boiled tubers can be consumed as mashed food, soup, and stew. It can be fried, to make crispy flakes. It can also be consumed as a drink. In Africa, yams are used to make a traditional meal called *fufu*, which consists of an elastic mass made of boiled, ground, and kneaded in a wooden mortar.

Moreover, yam (*Dioscorea spp.*) is a highly relevant crop to help achieve food safety, as it has excellent nutritional attributes, and broad adaptability to different edaphoclimatic conditions, thus contributing to productivity and tolerance to biotic and abiotic factors (Borges et al., 2016 and Sánchez, Labrada & Borges, 2019), and it is an important crop in the east of Cuba, with the highest diversity of *Dioscorea spp.* (Borges, Silva & Reyes, 2020).

Reduction of *Dioscorea spp.* losses through handling during harvest and post-harvest storage

Below are a set of steps to handle the crop, which is essential to reduce losses during the harvest and post-harvest storage of commercial tubers.

- To plant in 50 cm high rows (0.5x1 m), to avoid possible mechanical damage when harvesting.
- To perform the harvest between 8 and 9 months of plantation.
- If the apex is pale during the harvest sampling, it can be left resting on the soil for a reasonable time (2-3 weeks). If the apex is dark, very similar to the rest of the tuber, the harvest can proceed.

- Manual harvest using the hoe to prevent major mechanical damage.

- Washing must be done to eliminate the residues from the soil, and organic matter that attaches to the tuber.

- Storing the tubers hanging in loophole sacks, in a clean, aerated facility, at room temperature, and under indirect sunlight.

- Drying the tubers in the air in the shade to eliminate external humidity from the tubers, and minimize the attack of pests during transport and storage.

Conclusions

- The main diseases observed in commercial yam tubers at harvest were *Botryodiplodia theobromae*, *Penicillium spp., Aspergillus flavus*, *Link*.

- All the clones evaluated showed that when the storage time reaches 60 days, the fresh mass percentage is reduced, whereas there is an increase in the dry mass percentage.

- The storage of commercial yam tubers *D. alata*, clones *Criollo*, *Chino Blanco*, *Caballo*, *Caraqueño*, and *D. esculenta*, clone *Papa* was made successfully in loophole bags for up to 60 days in an aerated, clean facility with indirect sunlight, at room temperature.

- The organoleptic analysis showed that *Chino blanco* had the highest acceptance, with 100% panelists desiring to eat it again repeatedly. Then clones *Papa*, *Caraqueno*, and *Criollo* (80%), and lastly, *Caballo* (80%). According to 80% of the panelists, *Caballo* was the clone they did not desire to consume again.

- Several steps were designed to handle *Dioscorea spp.* during the harvest and post-harvest storage.

Recommendations

- To conduct further studies on the storage of commercial yam tubers *D. alata*, clones *Criollo*, *Chino Blanco*, *Caballo*, *Caraqueño*, and *D. esculenta*, clone *Papa* in loophole sacks for up to 180 days in an aerated, clean facility with indirect sunlight, at room temperature.

Author contribution

Misterbino Borges Garcia: research, morphological description of cultivars, analysis of results, redaction of the manuscript, final review.

Yoenia Sanchez Rodriguez: analysis of results and review of the manuscript.

Diana Maria Reyes Avalos: data collection and analysis of the results.

Conflict of interest

Not declared.

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