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Original Research Article

Influence of Conditioning and Storage Materials on the Germination Potential of Pumpkin (*Cucurbita* spp.) Seeds

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Abstract

This study was aimed at determining the germination potential of pumpkin (*Cucurbita spp.*) seeds stored in different materials and at different temperatures. Seeds were obtained from two *Cucurbita moschata* and one *Cucurbita maxima* pumpkin varieties. These seeds were stored in the laboratory at different temperatures: ambient temperature (25 ± 2°C), 5°C and -20°C. Germination tests were conducted at 30 days intervals during a 5 months period of seed conservation. After storage, the seeds were placed on paper napkins in Petri dishes moistened with distilled water. Germinated seeds were counted 10 days later and the length of each radicle was measured. Results revealed that pumpkin seeds are best stored at ambient temperature meanwhile viability is lost with long-term storage. At high humidity conditions, it is best to preserve pumpkin seeds in less water-permeable materials like cocked glass and plastic. Paper materials are best for preserving pumpkin seeds at ambient temperature. At this temperature, seeds from paper sachets showed 82% average germination rate, contrary to 76% at 5°C and only 34% at -20°C. Comparatively, seeds from glass material had 79% germination at ambient temperature, 77% at 5°C and 71% at -20°C.

Keywords

Cucurbita spp.
Germination
Pumpkin
Seed production
Storage conditions
Storage materials

Introduction

Pumpkin is a fruit of plants which belong to the genus *Cucurbita*. The plants of this genus are generally cultivated in warmer areas around the world and are economically and nutritionally important members of the *Cucurbitaceae* family (Saeid, 2006). Pumpkins have been reported in many countries of tropical Africa. They can be found in almost all regions of Cameroon and the most cultivated species are *Cucurbita maxima* and *Cucurbita moschata*. They are commonly used as a staple food and for medicinal purposes (Saha et al., 2011; Asgary et al., 2011; Jafarian et al., 2012). Pumpkin seed production is usually intended for propagation although some people consume the seeds in soup preparations. Having viable seeds will imply assuring propagation. The management of seeds after harvesting has been reported to play an essential role in posterior maintenance of yield and quality. The post-harvest treatments often considered include drying temperature, storage moisture content, storage conditions and duration (Daniels et al., 1998; Pearce et al., 2001). The three major aspects of seed quality are; genetic and physical purity, high germination percentage and vigour as well as their being free from insects and seed-borne diseases (Seshu and Dadlani, 1989).

Seeds have to be stored from harvest to the next planting season. Thus, safe seed storage is an important issue in agriculture (Mettananda et al., 2001). The ageing and loss of germination capacity of seeds cannot be stopped but can more or less be retarded by appropriate conservation conditions (Segnou et al., 2012). The storability of some seeds could be affected by the handling and treatment given to them before the planting season. Harrington (1958) reported that safe storage conditions are those which maintain seed quality without them losing vigour for three years. Delouche and co-workers (1973) pointed out that such conditions are not always economically justified. Long-term storability is mainly because biochemical activities are slowed down at low water content (Vertucci, 1989). Cucurbits like other orthodox seeds are best stored when the seed moisture content decreases by drying to about 5% (Styer et al., 1980). Drying to very low water content (about 1 - 2%) is harmful to most seeds (over-dried) and reduces their storability (Kong and Zhang, 1998). The two most important environmental inter-dependent factors which influence the loss of germination are relative humidity and conservation temperature; the more elevated these factors, the more rapid seeds deteriorate (Segnou et al., 2012).

Seeds of high quality are considered to be those with high vigour (Brocklehurst, 1985). Seed vigour is defined by the International Seed Testing Association as the total sum of those properties of the seed that determine the level of activity and performance of the seed during germination and seedling emergence (Fawad et al., 2002). Seed vigour is often evaluated by laboratory tests based on biochemical and biophysical characters (Bierhuizen and Feddes, 1973). According to Abram (2011) seed vigour and/or viability is a measure of the percentage of seeds that are alive after storage. Abram (2011) further explains that, the greater the viability of the seeds, the fewer seeds will be needed to establish a desired number of plants in the field or nursery. Seed viability (or germination potential) can be tested in many easy ways. To germinate and grow into seedlings, seeds need air, water, warmth, and light. Johnson and Wax (1978) attested that in many cases, laboratory tests of germination may predict performance in the nursery and field. Many internal and external factors affect seed vigour. These factors include storage materials and conditioning temperature since they provide different humidity conditions for the seeds as well as different liabilities for infection. Both storage conditions and duration are important factors affecting seed quality and the degree of biochemical changes in seeds (Kandil et al., 2013).

In Cameroon, pumpkin is mostly produced through subsistent farming and the farmers use various local bagging/storage materials to store these seeds based on their availability and the ease to use them. They keep the seeds under different conditions like in barns and kitchen shelves for varied periods. Since most of the seeds are used for propagation and home use, there is an acute scarcity (sometimes absence) within the markets and agricultural institutes. It is therefore indispensible for particular attention to be accorded to pumpkin seed handling and conservation. The influence of temperature and storage materials on pumpkin seeds conservation is not yet reported. This study was therefore carried out to evaluate the influence of storage materials, duration of storage and temperature on the germination potential of pumpkin (*Cucurbita spp.*) seeds.

Materials and methods

Three pumpkin fruit varieties including a variety of *Cucurbita maxima* (V1) and two varieties of *Cucurbita moschata* [‘Long-necked’ (V2) and Spherical (V3) types] were used (Fig. 1a). The pumpkins were collected from farmers in Bafia in the Center Region of Cameroon in July 2012 and authentified in Yaounde at the National Herbarium of Cameroon. Each variety from which seeds were extracted came from the same source and was harvested during the same season.

Laboratory work was carried out at the Plant Biotechnology and Environment Laboratory of the University of Yaounde I. Five different storage materials were used including; Aluminium sachets (AL), Glass tubes (GL), Plastic tubes (PL), Paper sachets (PA) and Polythene sachets (PO). Aluminium foil was shaped into small envelopes while the brown paper envelopes were reduced into smaller envelopes. The small polythene medicine (tablets) sachets were used to represent polythene bags while 'ready-made' test tube-like glass and plastic tubes with cocks were used for Plastic and Glass. The seeds were extracted manually from the fruits by breaking the fruits open into halves using a steel knife (Fig. 1b). The seeds were then washed with tap water after which they were selected by hand picking to remove bad seeds (seeds without cotyledon). This was done by feeling the seeds between the thumb and first finger.

After washing and selection, the seeds were wrapped into a clean towel to dry-off water from them. These seeds were then immediately placed on an electric balance and the readings recorded. Next they were spread to dry on slaps in the laboratory. Drying was done for approximately 10 days till a constant weight was obtained (Styer et al., 1980). The seeds of each fruit were divided into 15 parts (for the three conditioning temperatures and five storage materials) and placed in the respective conditions which included ambient temperature (25 ± 2°C), refrigerator (5°C) and freezer (-20°C) for 1-5 months from date of first storage. Over 4500 seeds were used in all with at least 1500 per variety. Three hundred seeds of each variety were placed in each storage material (with 100 seeds for each conditioning temperature). Twenty seeds from each storage material were then removed from storage monthly for germination test.

Fig. 1: Pumpkin fruits: a. The three pumpkin varieties (V1, V2 and V3); b. Longitudinal section of pumpkin fruits.

Germination test

Paper napkins were spread inside well labeled Petri dishes and moistened with distilled water. Twenty seeds of each variety and condition were singly placed on the moistened paper napkins. Another distilled water-moistened paper napkin was spread over the seeds and the Petri dishes covered to provide humid and appropriate germination conditions for the seeds. The Petri dishes were then placed in the laboratory at ambient temperature. The setup was checked at the end of the 10th day by carefully opening the over-layer of the hand napkins so the seeds could be seen. The seeds that germinated were counted and their numbers were recorded. The seeds were considered to have germinated once the radicle appeared. Using a 20 cm meter rule, the radicle length of each root was measured.

Statistical analysis

Statistical analysis was performed using SPSS version 16 following a split plot design. The monthly means were used to plot mean cumulative germination curves against time while multiple comparison of means was done by the Student-Newman-Keul method.

Results

All of the varieties used in this experiment showed highest germination potential during the first month and persisted or gradually reduced in the subsequent months (Figs. 2, 3 and 4).

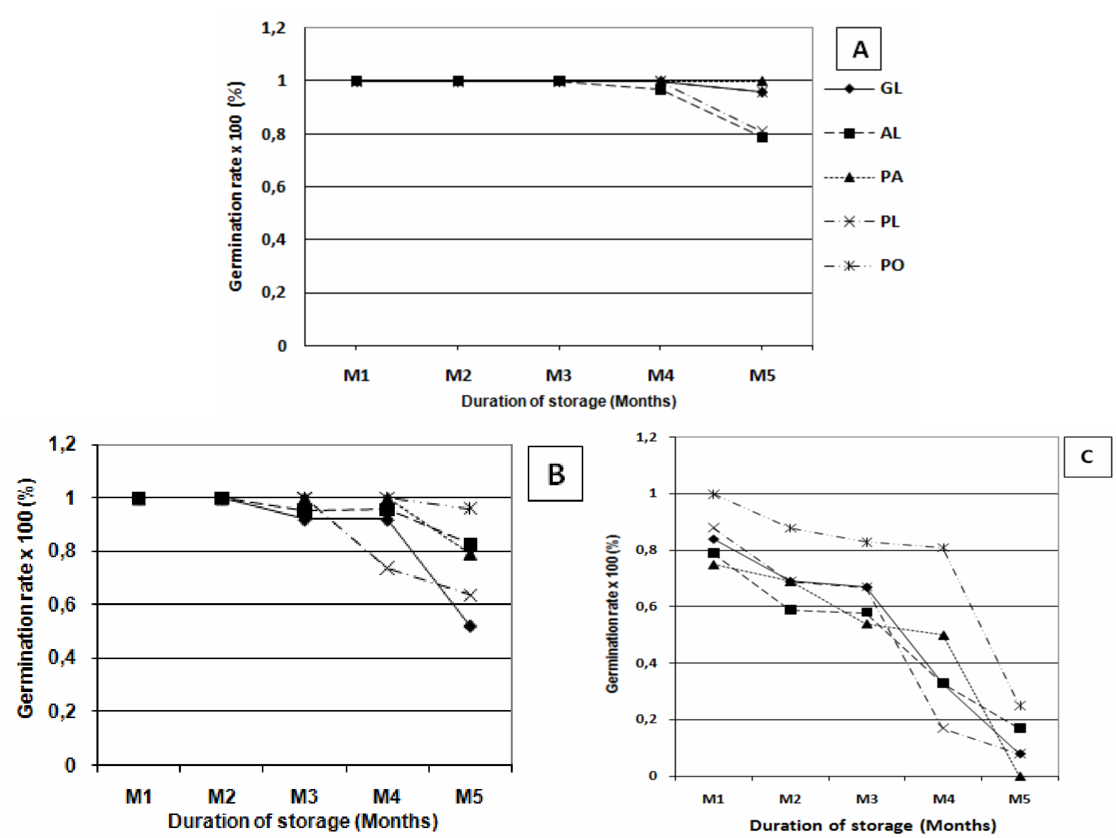

Fig. 2: Evolution of germination rate (%) with time (Month) of Pumpkin seeds stored at ambient temperature. A: V1, B: V2, C: V3, GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet.

Also, there was a consistent drop in germination potential within each variety from ambient through refrigeration to freezing temperature (Table 1). Furthermore, V1 generally germinated best in all the situations compared to V2 and V3 with V3 generally presenting worst results. However, they behaved differently with respect to the various storage materials at the various temperatures and conditions (Tables 2, 3 and 4).

Table 1. Overall average germination rate over the entire five months period.

Variety	Temperature	Storage materials					Average
		GL	AL	PA	PL	PO	
V1	AMB	0.99±0.02	0.95±0.09	1.00±0.00	0.96±0.08	0.99±0.02	0.98±0.02
	REF	0.98±0.02	0.96±0.06	0.99±0.02	0.98±0.04	0.96±0.04	0.98±0.01
	FRE	0.99±0.02	0.56±0.42	0.54±0.51	0.95±0.06	0.96±0.05	0.80±0.23
V2	AMB	0.87±0.20	0.95±0.07	0.96±0.09	0.88±0.17	0.99±0.02	0.93±0.05
	REF	0.93±0.14	0.86±0.14	0.91±0.11	0.90±0.10	0.87±0.22	0.89±0.03
	FRE	0.78±0.33	0.41±0.46	0.29±0.31	0.76±0.34	0.70±0.35	0.59±0.22
V3	AMB	0.52±0.31	0.49±0.24	0.50±0.30	0.50±0.35	0.75±0.29	0.55±0.11
	REF	0.39±0.30	0.53±0.12	0.39±0.10	0.31±0.15	0.39±0.26	0.40±0.08
	FRE	0.36±0.14	0.30±0.28	0.19±0.28	0.39±0.28	0.42±0.23	0.33±0.09

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet, AMB: Ambient temperature (25±2°C), REF: Refrigeration temperature (5°C), FRE: Freeing temperature (-20°C).

Table 2. Germination rate (%) over the entire five months period for seeds from ambient temperature.

Variety	Storage materials				
	AL	GL	PA	PL	PO
V1	0.95 ± 0.09	0.99 ± 0.02	1.00 ± 0.00	0.96 ± 0.08	0.99 ± 0.02
V2	0.95 ± 0.07	0.87± 0.20	0.96 ± 0.09	0.88 ± 0.17	0.99 ± 0.02
V3	0.49 ± 0.24	0.52 ± 0.31	0.50 ± 0.30	0.50 ± 0.35	0.39 ± 0.26
Average	0.80 ± 0.27a	0.79 ± 0.24a	0.82 ± 0.28a	0.78 ± 0.25a	0.79 ± 0.35a

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet, AMB: Ambient temperature (25±2°C), REF: Refrigeration temperature (5°C), FRE: Freeing temperature (-20°C). Average values with same alphabet between columns do not differ significantly at $p<0.05$.

Table 3. Germination rate (%) over the entire five months period for seeds from refrigeration temperature.

Variety	Storage materials				
	AL	GL	PA	PL	PO
V1	0.96 ± 0.06	0.98 ± 0.02	0.99 ± 0.02	0.98 ± 0.04	0.96 ± 0.04
V2	0.86 ± 0.14	0.93 ± 0.14	0.91 ± 0.11	0.90 ± 0.10	0.87 ± 0.22
V3	0.53 ± 0.12	0.39 ± 0.30	0.39 ± 0.10	0.31 ± 0.15	0.39 ± 0.26
Average	0.78 ± 0.23a	0.77 ± 0.33a	0.76 ± 0.33a	0.73 ± 0.37a	0.74 ± 0.31a

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet, AMB: Ambient temperature (25±2°C), REF: Refrigeration temperature (5°C), FRE: Freeing temperature (-20°C). Average values with same alphabet between columns do not differ significantly at $p<0.05$.

Table 4. Germination rate (%) over the entire five months period for seeds from freezing temperature.

Variety	Storage materials				
	AL	GL	PA	PL	PO
V1	0.56 ± 0.42	0.99 ± 0.45	0.54 ± 0.51	0.95 ± 0.06	0.96 ± 0.05
V2	0.41 ± 0.46	0.78 ± 0.33	0.29 ± 0.31	0.76 ± 0.34	0.70 ± 0.35
V3	0.30 ± 0.28	0.36 ± 0.14	0.19 ± 0.28	0.39 ± 0.28	0.42 ± 0.23
Average	0.42 ± 0.13a	0.71 ± 0.32a	0.34 ± 0.18a	0.70 ± 0.28a	0.69 ± 0.27a

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet, AMB: Ambient temperature (25±2°C), REF: Refrigeration temperature (5°C), FRE: Freeing temperature (-20°C). Average values with same alphabet between columns do not differ significantly at $p<0.05$.

Effect of material and duration of storage on the germination potential of pumpkin seeds stored at ambient temperature

Seeds of V1 recorded relatively best results with storage materials like PA recording 100% germination rate for all five months (Fig. 2A). Apart from AL (100 % up to the 3rd month), all other storage materials showed 100% germination rate for up to the 4th month with the lowest for the 5th month recording as high as 79 % (AL). In the case of V2 (Fig. 2B), there was 100% germination rate for all storage materials for the first two months and by the third month, differences set in while seeds of V3 (Fig. 2C) recorded relatively lowest germination rates with the best rate for the 5th month as low as 25% (PO).

Effect of material and duration of storage on the germination potential of pumpkin seeds stored at refrigeration temperature

In the case of V1 (Fig. 3A), four of the five storage materials sustained a 100% germination rate for the first three months before negative trends set in. Viability was generally highest in this variety. Very high germination rates were even noticed up to the 5th month, the lowest being 86% (AL). V2 on its part (Fig. 3B), recorded a 100% germination rate for the first two months and differed by the 3rd month. Again, V3 (Fig. 3C) recorded relatively worst results. GL for instance, with a germination rate of 84% by the first month, dropped to as low as 0% by the 5th month.

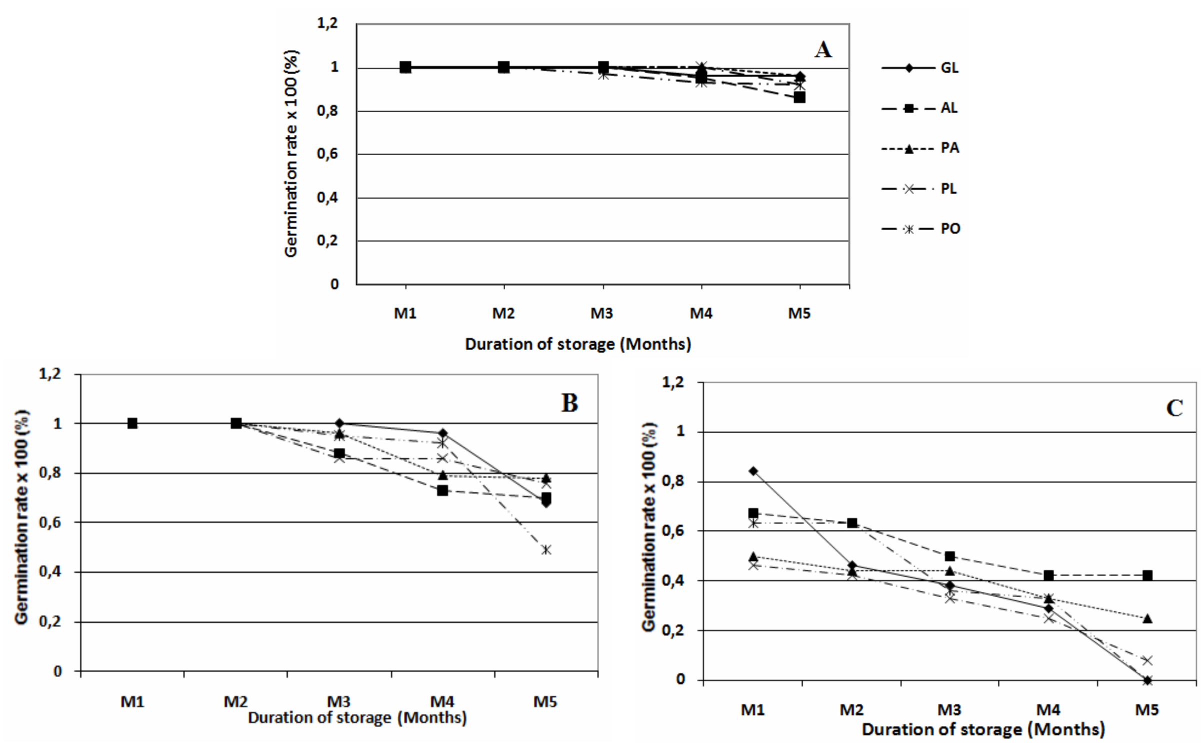

Fig. 3: Evolution of germination rate (%) with time (Month) of Pumpkin seeds stored at -5°C.
A: V1, B: V2, C: V3, GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet.

Effect of material and duration of storage on the germination potential of pumpkin seeds stored at freezing temperature

Comparatively, freezing temperature of storage gave the worst results. In all three varieties, 0% germination rates could be noticed for as early as the 3rd month in V3 and 4th month for V2 and V1. Seeds of V1 (Fig. 4A) generally showed best germination rates. Apart from the seeds in AL, all the other storage materials showed 100% germination for at least the first two months before the adverse effects of ageing on germination set in. Again PA and AL in this case showed remarkably poor results especially by the 4th and 5th months. In the case of V2 (Fig. 4B), only the seeds in GL could attain a 100% germination rate for the first three months and by the 4th month, there was no germination in seeds from PA and AL. Germination rates were lowest in V3 (Fig. 4C) with none of the storage materials attaining 100% for any of the months, not even the first month.

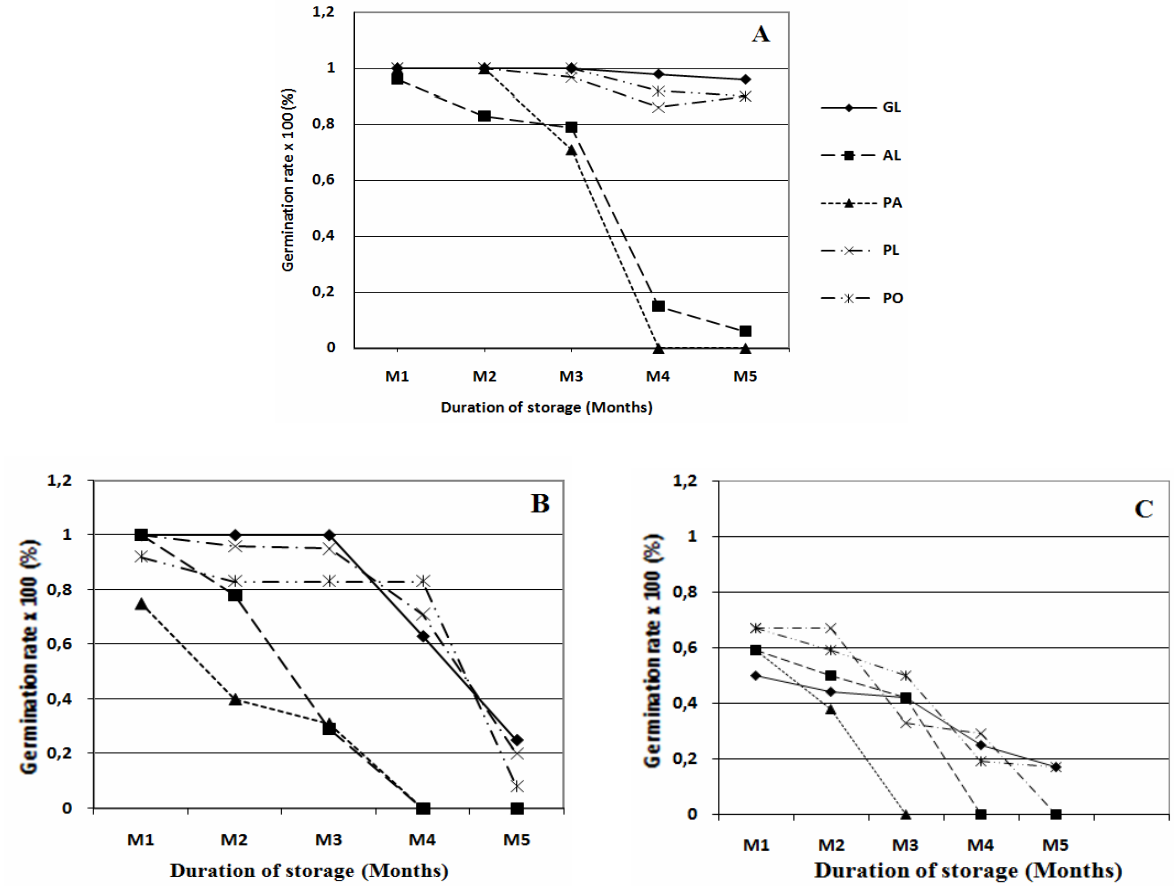

Fig. 4: Evolution of germination rate (%) with time (Month) of pumpkin seed stored at -20°C.
A: V1, B: V2, C: V3 GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet.

Length of radicle

The radicle length of pumpkin seeds stored at ambient, refrigeration and freezing temperatures were totally consistent with germination results in all situations. Hence they were used as a supportive data. Root lengths reduced with age as well as with colder temperatures are shown in Tables 5, 6 and 7.

Table 5. Average monthly radicle length of germinated pumpkin seeds stored at ambient temperature.

Treatment	M1	M2	M3	M4	M5
V1AL	2.07 ± 0.67ab	1.11 ± 0.59ab	1.07 ± 0.49a	0.95 ± 0.52abc	0.72 ± 0.21a
V1GL	2.21 ± 0.96ab	1.03 ± 0.54ab	0.82 ± 0.45a	0.72 ± 0.26abc	0.63 ± 0.26a
V1PA	1.86 ± 0.60a	1.21 ± 0.41ab	0.92 ± 0.31a	0.72 ± 0.65abc	0.60 ± 0.32a
V1PL	2.62 ± 0.79ab	1.35 ± 0.36a	1.14 ± 0.86a	1.13 ± 0.51abc	0.65 ± 0.28a
V1PO	2.42 ± 0.82ab	1.81 ± 1.23ab	1.02 ± 0.36a	0.88 ± 0.36abc	0.58 ± 0.31a
V2AL	3.08 ± 1.09ab	1.35 ± 1.12ab	1.14 ± 0.57a	0.63 ± 0.49ab	0.54 ± 0.41a
V2GL	2.56 ± 0.84ab	1.01 ± 0.66ab	0.71 ± 0.42a	0.58 ± 0.85abc	0.44 ± 0.27a
V2PA	3.43 ± 1.13ab	1.25 ± 1.43ab	1.15 ± 0.79a	1.15 ± 1.22abc	0.60 ± 0.48a
V2PL	2.40 ± 1.02ab	1.42 ± 0.48ab	0.93 ± 0.43a	0.59 ± 0.34abc	0.55 ± 0.40a
V2PO	3.79 ± 0.63a	1.62 ± 0.46ab	1.03 ± 0.61a	0.51 ± 0.28abc	0.46 ± 0.79a
V3AL	1.97 ± 0.40ab	1.23 ± 1.42ab	0.68 ± 0.47a	0.63 ± 0.92a	0.30 ± 0.20a
V3GL	1.33 ± 1.29b	0.58 ± 0.46ab	0.53 ± 0.46a	0.31 ± 0.53abc	0.00 ± 0.00a
V3PA	1.06 ± 0.78b	0.28 ± 0.38ab	0.81 ± 0.83a	0.25 ± 0.25c	0.11 ± 0.08a
V3PL	1.90 ± 2.19ab	1.38 ± 2.75b	0.66 ± 1.26a	0.03 ± 0.05bc	0.18 ± 0.17a
V3PO	2.18 ± 1.78ab	0.27 ± 0.41ab	0.17 ± 0.19a	0.13 ± 0.19c	0.00 ± 0.00a

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet. Average values with same alphabet between columns do not differ significantly at $p<0.05$.

Table 6. Average monthly radicle length of germinated pumpkin seeds stored at refrigeration temperature.

Treatment	M1	M2	M3	M4	M5
V1AL	2.07 ± 0.67ab	1.11 ± 0.59ab	1.07 ± 0.49a	0.95 ± 0.52abc	0.72 ± 0.21a
V1GL	2.21 ± 0.96ab	1.03 ± 0.54ab	0.82 ± 0.45a	0.72 ± 0.26abc	0.63 ± 0.26a
V1PA	1.86 ± 0.60a	1.21 ± 0.41ab	0.92 ± 0.31a	0.72 ± 0.65abc	0.60 ± 0.32a
V1PL	2.62 ± 0.79ab	1.35 ± 0.36a	1.14 ± 0.86a	1.13 ± 0.51abc	0.65 ± 0.28a
V1PO	2.42 ± 0.82ab	1.81 ± 1.23ab	1.02 ± 0.36a	0.88 ± 0.36abc	0.58 ± 0.31a
V2AL	3.08 ± 1.09ab	1.35 ± 1.12ab	1.14 ± 0.57a	0.63 ± 0.49ab	0.54 ± 0.41a
V2GL	2.56 ± 0.84ab	1.01 ± 0.66ab	0.71 ± 0.42a	0.58 ± 0.85abc	0.44 ± 0.27a
V2PA	3.43 ± 1.13ab	1.25 ± 1.43ab	1.15 ± 0.79a	1.15 ± 1.22abc	0.60 ± 0.48a
V2PL	2.40 ± 1.02ab	1.42 ± 0.48ab	0.93 ± 0.43a	0.59 ± 0.34abc	0.55 ± 0.40a
V2PO	3.79 ± 0.63a	1.62 ± 0.46ab	1.03 ± 0.61a	0.51 ± 0.28abc	0.46 ± 0.79a
V3AL	1.97 ± 0.40ab	1.23 ± 1.42ab	0.68 ± 0.47a	0.63 ± 0.92a	0.30 ± 0.20a
V3GL	1.33 ± 1.29b	0.58 ± 0.46ab	0.53 ± 0.46a	0.31 ± 0.53abc	0.00 ± 0.00a
V3PA	1.06 ± 0.78b	0.28 ± 0.38ab	0.81 ± 0.83a	0.25 ± 0.25c	0.11 ± 0.08a
V3PL	1.90 ± 2.19ab	1.38 ± 2.75b	0.66 ± 1.26a	0.03 ± 0.05bc	0.18 ± 0.17a
V3PO	2.18 ± 1.78ab	0.27 ± 0.41ab	0.17 ± 0.19a	0.13 ± 0.19c	0.00 ± 0.00a

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet. Average values with same alphabet between columns do not differ significantly at $p<0.05$.

Table 7. Average monthly radicle length of germinated pumpkin seeds stored at freezing temperature (-20°C).

Treatment	M1	M2	M3	M4	M5
V1AL	2.02 ± 2.27b	1.50 ± 0.56b	0.93 ± 0.93a	0.18 ± 0.27ab	0.03 ± 0.18c
V1GL	1.93 ± 1.55b	1.91 ± 0.84ab	1.10 ± 0.72a	1.07 ± 0.11ab	0.84 ± 0.33a
V1PA	1.26 ± 0.49b	1.16 ± 1.07b	1.11 ± 0.35a	0.00 ± 0.00b	0.00 ± 0.00c
V1PL	1.26 ± 0.53b	1.85 ± 0.91ab	0.75 ± 0.57a	0.75 ± 0.33ab	0.82 ± 0.20ab
V1PO	1.47 ± 0.39b	1.27 ± 0.88b	1.14 ± 0.52a	0.73 ± 0.16ab	0.53 ± 0.31abc
V2AL	4.02 ± 1.67a	2.71 ± 2.57ab	1.22 ± 1.32a	0.00 ± 0.00b	0.00 ± 0.00c
V2GL	1.86 ± 1.67b	1.79 ± 0.78ab	1.23 ± 1.12a	1.18 ± 0.87ab	0.45 ± 0.81bc
V2PA	1.48 ± 1.27b	1.37 ± 1.61b	0.07 ± 0.16a	0.00 ± 0.00b	0.00 ± 0.00c
V2PL	3.53 ± 2.29b	1.21 ± 0.92ab	1.15 ± 0.67a	0.78 ± 0.59ab	0.33 ± 0.59bc
V2PO	4.09 ± 2.24a	1.73 ± 1.60ab	1.33 ± 0.69a	1.01 ± 0.76a	0.32 ± 0.60bc
V3AL	5.40 ± 3.91b	1.98 ± 1.65a	0.79 ± 0.93a	0.00 ± 0.00b	0.00 ± 0.00c
V3GL	0.99 ± 0.99b	0.89 ± 0.73b	0.68 ± 0.92a	0.47 ± 0.75ab	0.43 ± 0.49bc
V3PA	1.99 ± 1.44b	1.48 ± 1.48b	0.00 ± 0.00a	0.00 ± 0.00b	0.00 ± 0.00c
V3PL	1.53 ± 2.46b	0.75 ± 0.70b	0.74 ± 0.95a	0.15 ± 0.17ab	0.00 ± 0.00c
V3PO	2.21 ± 2.18b	1.28 ± 1.36ab	1.17 ± 1.18a	0.96 ± 1.06ab	0.14 ± 0.27bc

GL: Glass tube, AL: Aluminium sachet, PA: Paper sachet, PL: Plastic tube, PO: Polythene sachet. Average values with same alphabet between columns do not differ significantly at $p<0.05$.

Discussion

Effect of storage duration on germination of pumpkin seeds

Generally, the best results on the duration of storage were obtained with seeds of the earlier months. The results dropped with the later months. It is evident that the longer the seeds are kept before planting, the more they loss their germination potential. Hence ageing brings in an adverse effect on the germination of pumpkin seeds, reason why they loss their germination potential with time. The fifth month showed the worse results. However, V2 and V1 showed good germination for the first three months of storage and relatively poor germination subsequently. These two varieties by the 5th month still showed good germination rate in the case of seeds at ambient temperature and 5°C; an indication that pumpkin seeds remain viable even above five months in these storage conditions. The drop in germination rate with time could simply be as a result of senescence which usually comes with loss in physiological efficiency. Segnou and co-workers (2012) reported that this cannot be stopped but can more or less be retarded by appropriate conservation conditions. According to

Shelar and collaborators (2008), the rapid seed deterioration of oil seeds is thought to be due to lipid peroxidation, subsequently resulting in loss of seed viability. Different periods of seed ageing adversely affect seed quality (Tatic et al., 2009).

Influence of storage materials on the germination of pumpkin seeds

There was no consistency in the results obtained with regards to the influence of the storage materials. None of the storage materials presented distinct and consistent results any variety or conditioning temperature. Different results were obtained with seeds of the different varieties though from the same conditions. It is therefore most likely that the storage materials used here influence germination depending on the temperature at which they were placed. Storage materials normally influence the environmental factors around the seeds. Joao and Lovato (1999) working on maize seeds explained that seed moisture and relative humidity are important in safe storage. However, pumpkin seeds are large enough coupled with the presence of a thick and hard coat which minimize the effect of most of these environmental factors (like humidity).

Moreover, if ensured that the seeds are really of low water content, biochemical activities would be slowed down and this is probably more responsible for long storability (Vertucci, 1989) than storage materials in the case of pumpkins. It should be noted, however, that seeds with thinner coats can be more sensitive to environmental factors than is the case with pumpkins. Each material influences the environmental humidity of its seeds differently. For instance, the GL, PL and PO materials used in this study were tightly cocked or sealed. Hence, while in the freezer or refrigerator, the seeds remained relatively dry. Joao and Lovato (1999) have also suggested that seeds should be packed in waterproof materials for long-term storage. This justifies why seeds from these materials at freezing temperature showed better germination rates than those from AL and PA. Seeds from PA at freezing temperature, however, distinguished themselves with a very poor germination rate. This could probably be because of relatively high moisture and humidity as the paper bags and seeds were even wet and covered with ice. This facilitates deterioration and encourages fungal growth (Boelema, 1981) as was observed. However, PA as well as AL recorded better results for seeds at ambient temperatures while GL, PO and PL recorded though good, but relatively poorer results. These three materials are less/not permeable to water and since this experiment was carried out during a dryer and hotter season, it is most likely that they rather made conditions more humid for the seeds easing deterioration unlike paper that easily allows water from seeds to permeate out into the atmosphere leaving the seeds dry and dormant and preventing deterioration.

Influence of conditioning temperature on pumpkin seed germination

Generally, ambient temperature and 5°C proved appropriate for pumpkin seed storage while seeds at -20°C showed relatively poor germination rates. Segnou and co-workers (2012) explained that the more elevated the humidity, the more rapid seeds deteriorate. A study in Sri Lanka on maize seed storage has demonstrated that good storability could be obtained if they are stored at low relative humidity (Silva, 1987). This could be responsible for this trend of results as humidity is normally higher at freezing temperatures than at refrigeration and lowest at ambient temperatures. Higher humidity conditions encourage infections like fungal growths which directly affect (negatively) germination. This aspect was observed in the case with seeds from the freezer. A few days after removal from the freezer, infections developed on the seeds. Donalson and co-workers (1986) in their article "Pest of Cucurbits" advanced the 'infection of pumpkin seeds' as one of the reasons responsible for poor growth and yield. On their part, Nel and co-workers (2002) attested that high humidity encourages fungal growth on seeds.

This could be further explained by the fact that the seeds remain biochemically active in more humid conditions (presence of water) and this of course hastens deterioration than in dryer conditions where biochemical activity is reduced (Vertucci, 1989). Just like any other organism would have minimum, optimal and maximum physiological temperatures, a freezing temperature of -20^{o}C probably denatures most of the enzymes of the pumpkin seeds, contributing to the reasons for the very poor germination rates of the pumpkin seeds from freezer.

Relationship between germination rate and length of radicle

The trends of results obtained from root length were consistent with those of germination. This is supportive to the general results. A viable seed that germinates well and fast should obviously grow fast provided the milieu possesses no obstacle to root growth. However, subsequent growth will somehow depend on nutrient availability; the timing of this aspect of the experiment did not have to go too long such that this could set in. The adverse effects of ageing on germination are also expressed in the radicle (first root) growth thus justifying the results.

Conclusion

Considered medicinal for more than 3000 years in different parts of the globe, pumpkin seeds have a remarkable array of health benefits. Packed with magnesium, calcium, potassium, iron, zinc, and vitamins, these tasty traits make pumpkin seeds to be rated as one of the world's healthiest foods and should be considered in regular food recipes. To increase availability, attention must be paid to seed handling and storage, which are aspects that can negatively influence the germination potential of the seeds. Pumpkin seeds are best stored at ambient temperature as well as at 5°C, but temperatures equal to or lower than -20°C should be discouraged. In essence, ambient temperatures would be appropriate if pumpkin seeds are to be preserved for a long period of time before planting. Moreover, viability is lost with long-term storage as well as it is best to preserve these seeds in less water-permeable materials like cocked glasses and plastics, especially when stored in humid conditions. Paper materials are best for preserving pumpkin seeds at ambient temperature in dryer conditions. A good germination assures production and of course, ensures and increases availability of seeds and their eventual agricultural products.

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