Pak. J. Bot., 58(10): 2154-2158, October 2026.

ARTICLE | DOI: http://dx.doi.org/10.30848/PJB2026-10(6)

PACKAGING AND ENVIRONMENTAL CONDITIONS AFFECT THE PHYSIOLOGICAL QUALITY OF PITAYA SEEDS (*HYLOCEREUS UNDATUS*) DURING 12 MONTHS OF STORAGE

THIAGO ALBERTO ORTIZ[1,2], D.S. AMANO[1], D.R. THOMAZ[2] AND L.S.A. TAKAHASHI[1]

[1]Department of Agronomy, Universidade Estadual de Londrina (UEL), Londrina, Brazil
[2]Graduate Program in Biotechnology Applied to Agriculture, Universidade Paranaense (UNIPAR), Umuarama, Brazil

*Corresponding author's email: thiago.ortiz@homail.com

Abstract

Pitaya encompasses a group of exotic cactus species, with the genus *Hylocereus* being valued for both its nutritional benefits and the distinctive characteristics of its fruit. Since this species can be propagated by seeds, it is essential to evaluate storage conditions to determine those that best preserve the physiological quality of seed batches. This study aims to assess the physiological quality of pitaya seeds stored under different packaging and environmental conditions over a 12-month period. The experiment was conducted with *Hylocereus undatus* seeds using a completely randomized design with 4 replications of 50 seeds each, arranged in a 3 × 3 × 12 factorial scheme [packaging (white Kraft paper bag, polythene bag, and polypropylene bag), storage environment (ambient, refrigerator, and cold chamber), and storage duration (from 1st to 12th month, monthly)]. To evaluate seed physiological quality, a germination test was performed, and the variables analyzed included germination percentage, germination speed index (GSI), and mean germination time (MGT). The data were subjected to analysis of variance, and significant results were further analyzed using regression models with quadratic terms. Pitaya seeds (*H. undatus*) stored in a cold chamber retained their physiological quality in paper, polythene, or polypropylene packaging over 12 months. In contrast, under other storage conditions, the storage period should be reduced due to its negative impact on the physiological quality of pitaya seeds.

Key words: Germination; Seed conservation; Seed quality; Storage temperature; Vigor.

Introduction

Pitaya comprises a group of exotic cacti species from the genera *Hylocereus* or *Selenicereus*, known for their distinctive and striking fruits. Commonly referred to as "dragon fruit" (*Hylocereus undatus* [Haworth] Britton and Rose), this agri-food crop is valued for its exotic appearance, high nutritional value, and its antioxidant properties, including selective cytotoxic activity, organic acids, tocopherols, and betacyanins (Pasko *et al*., 2021; Roriz *et al*., 2022).

This species can be propagated through seeds, stem cuttings, and grafting (Anagha *et al*., 2024). However, some studies report that seeds exhibit a low germination percentage and a prolonged germination period due to the unique structure of the ovule, as well as their recalcitrant nature (Vishnupriya *et al*., 2019). Additionally, seed viability decreases significantly when stored at low temperatures (Dahanayake & Ranawake, 2011).

Seed longevity plays a crucial role in the conservation of plant germplasm, species reproduction and distribution, as well as crop yield and quality, and food safety. During storage, longevity and vigor decline, negatively affecting germination and seedling establishment (Rehmani *et al*., 2023). Given that conditioned storage facilities might be inaccessible or costly, alternative methods, especially for on-farm storage, should be explored. Effective storage is vital in seed programs to maintain seed quality from harvest to sowing, manage stocks for trade, provide a buffer against crop failures, support hybrid seed production, conserve genetic stocks for breeding, and preserve germplasm for long-term use (Dadlani & Yadava, 2023).

Although several factors—such as storage temperature, relative humidity, and seed moisture content—affect the physiological and sanitary quality of seed batches during storage, all seeds undergo deteriorative changes over time, even under dry conditions. These changes primarily impact germination and vigor due to physiological and sanitary deterioration. A well-designed seed program aims to maintain high planting value in terms of purity, germination, vigor, and seed health during storage by controlling the temperature and relative humidity of the storage environment (Dadlani and Yadava, 2023).

According to Assaye & Alemayehu (2023), one of the most critical processes for maintaining seed quality is the post-harvest stage, which includes storage. The type of packaging material and storage environment significantly impact the seed's shelf life. Different packaging materials have unique properties, making it essential to research the effects of locally available options, such as paper, polyethylene, and polypropylene bags.

Given the importance of safe storage for maintaining seed vigor and viability, this study aims to evaluate the physiological quality of pitaya seeds stored under different packaging and environmental conditions over a 12-month period.

Received: 26-05-2025 | Revised: 15-12-2025 | Accepted: 22-12-2025 | Online: 13-05-2026

Material and Methods

The study was conducted at the Seed Laboratory, Department of Agronomy, Center of Agricultural Sciences, Universidade Estadual de Londrina (UEL), Londrina, PR, Brazil. It employed a completely randomized design with 4 replications, following a 3 × 3 × 12 factorial scheme (packaging × storage environment × storage period).

To obtain pitaya seeds, the pulp of ripe fruits (*Hylocereus undatus*) was manually macerated, and water and sugar (25 $g.L^{-1}$) were added to promote the fermentation process for 48 hours. This was done in the shade at an ambient temperature of approximately 25°C. After this period, the solution was washed with running water using a sieve to remove pulp residues and retain only the seeds. The seeds were then left to dry at room temperature for 48 hours on paper towels.

After obtaining the seeds, they were placed in different storage conditions based on the treatments. Three types of packaging were used: white Kraft paper bags, polythene bags, and polypropylene bags. The experimental units were then placed in three storage environments: ambient (temperature ≈ 6.0-32.4°C and relative humidity ≈ 30.6-67.3%), refrigerator (temperature ≈ 9.9-21.1°C and relative humidity ≈ 44.4-94.3%), and cold chamber (temperature = 12.0°C and relative humidity = 45.0%). The seeds were stored for twelve periods: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 months, according to each treatment.

To evaluate the physiological quality of the pitaya seeds, a germination test was conducted after each storage period, with four replications of 50 seeds each. The seeds were placed on blotting paper moistened with distilled water at a rate of 2.5 times the dry mass of the substrate, in a crystal polystyrene box (11.0 × 11.0 × 3.5 cm). Germination was assessed daily for 21 days, until the germination process stabilized. The variables analyzed were germination percentage, germination speed index (GSI) according to the methodology proposed by Maguire (1962), and mean germination time (MGT, in days) according to Lima *et al*. (2006).

The data were subjected to analysis of variance, and when significant, adjustments were made using regression models with quadratic terms for the variables germination, GSI, and MGT, using the Sisvar® software.

Results and Discussion

The triple interaction among the factors "packaging," "storage environment," and "storage period" showed a significant difference for the variables germination, germination speed index, and mean germination time (Table 1).

From Fig. 1, it is evident that in all the packaging types evaluated (paper, polythene, and polypropylene), the ambient storage condition was unsuitable for pitaya seed storage. Specifically, just 1 month of storage was sufficient to reduce the germination percentage by approximately 10.0% in both polythene and polypropylene packaging. After 4 months of storage, the paper bag reduced the germination percentage from 92.5% to 60.0%. In contrast, seeds stored in polythene and polypropylene bags showed a more severe reduction, with germination percentages of 14.0% and 17.0%, respectively.

Table 1. *p*-values for the variables germination (%), germination speed index (GSI), and mean germination time (MGT - days) of pitaya seeds (*Hylocereus undatus*) under different packaging types (paper, polythene, and polypropylene) and storage environments (ambient, refrigerator, and cold chamber) over 12 months.

Germination	***p*-value**
Packaging (P)	0.0000^{*}
Storage environment (SE)	0.0000^{*}
Storage period (SP)	0.0000^{*}
P × SE	0.0000^{*}
P × SP	0.0000^{*}
SE × SP	0.0000^{*}
P × SE × SP	0.0000^{*}
CV (%)	12.90
Germination speed index	***p*-value**
Packaging (P)	0.0000^{*}
Storage environment (SE)	0.0000^{*}
Storage period (SP)	0.0000^{*}
P × SE	0.0000^{*}
P × SP	0.0001^{*}
SE × SP	0.0000^{*}
P × SE × SP	0.0000^{*}
CV (%)	21.23
Mean germination time	***p*-value**
Packaging (P)	0.3527^{NS}
Storage environment (SE)	0.0000^{*}
Storage period (SP)	0.0000^{*}
P × SE	0.0000^{*}
P × SP	0.0138^{NS}
SE × SP	0.0000^{*}
P × SE × SP	0.0000^{*}
CV (%)	34.00

^{NS} Non-significant, * Significant $p<0.05$

Many studies focus on evaluating the storage of agricultural products in the absence of oxygen. However, the present research specifically aimed to identify viable storage conditions for small and family-run farms. According to Lamsal & Baributsa (2023), current oxygen scavengers used to remove residual oxygen are often unavailable and unsuitable, particularly for smallholder farms in developing countries.

In the present study, storing pitaya seeds in a refrigerator with paper packaging was effective for maintaining seed quality over 12 months, with only an 8% reduction in germination (from 92.5% to 84.5%). Conversely, storing pitaya seeds in a refrigerator with polythene packaging was viable for only 2 months; from the 3rd month onward, germination declined by 30% or more (Fig. 1). For wheat seeds, Kadam *et al.,* (2023) found that seeds stored in polythene bags exhibited good germination percentages, with polythene bags being effective in maintaining germination up to 12 months under cold storage conditions. This finding differs from what was observed for pitaya seeds.

Kadam *et al*., (2023) suggested that seeds stored in polythene bags under cold storage conditions could extend the storage life of wheat seeds to 32 months, while still meeting Indian minimum seed certification standards (IMSCS) of 85%.

Storing pitaya seeds under refrigerator conditions with polypropylene packaging was effective for only 3 months, due to a loss of approximately 25% in germination over longer periods (Fig. 1). The cold chamber provided suitable conditions for storing pitaya seeds in all three packaging types evaluated over 12 months, achieving germination

rates of approximately 90% (87.5% for paper and polythene bags, and 93.5% for polystyrene bags) (Fig. 1). Kadam *et al*., (2023), who assessed four wheat varieties under two storage conditions (ambient and low temperature) and five types of containers (gunny bag, cloth bag, polythene bag, high-density polyethylene bag, and pro-grain bag) over 12 months, concluded that low-temperature storage (20°C) was the most effective for maintaining wheat germination.

When evaluating the germination speed index (GSI), it was observed that the ambient condition and paper packaging were only adequate for pitaya seeds for 1 month of storage, after which the GSI tended to decrease progressively. The ambient condition, along with polythene and polypropylene packaging, was not suitable for storing pitaya seeds, as a reduction in GSI was already noticeable from the 1st month of storage (Fig. 2).

The refrigerator condition, with polythene and polypropylene packaging, was suitable for storing pitaya seeds for only 2 and 3 months, respectively (Fig. 2), exhibiting a similar trend to that observed for the germination variable (Fig. 1).

As with the germination variable, the cold chamber condition proved favorable for pitaya seed storage in all packaging types, with an increase in GSI up to the 12th month, confirming its suitability for storing the seeds of this species. Additionally, it was found that the refrigerator and paper packaging are suitable for storing pitaya seeds for up to 12 months (Fig. 2).

Assaye & Alemayehu (2023) assessed how rice seed quality varied with different storage durations (6, 12, and 18 months) and packaging types (Purdue Improved Crop Storage bag - PICS, Super GrainPro bag, jute bag, polypropylene bag, and fertilizer bag). They found that while the germination percentage of rice seeds remained above the recommended standard, both germination and seedling vigor decreased over time. Significant differences in seed quality were observed across the packaging types at 6, 12, and 18 months. The Ediget variety seeds stored in PICS and Super GrainPro bags exhibited better germination, seedling length and dry weight, and vigor compared to those in jute bags, making PICS and Super GrainPro bags the preferred options for on-farm rice seed preservation.

When evaluating the mean germination time (MGT) variable, it is observed in Figure 3 that the ambient condition, regardless of the packaging used, led to an increase in MGT from the 1st month of storage. This indicates that under ambient conditions, the seed vigor is reduced, requiring more time for the germination process and thus being more vulnerable to adverse field conditions such as drought, frost, and pest or pathogen attacks.

The refrigerator condition, with paper packaging, was viable in terms of the MGT variable for up to 5 months of storage. However, for polythene and polypropylene bags in the refrigerator, MGT was favorable for 2 and 3 months, respectively, showing similar behavior to that observed for the germination (Fig. 1) and germination speed index (GSI) (Fig. 2) variables.

Demir & Kadioğlu (2024), when evaluating the effects of oxygen availability in seed containers on germination in tomato, onion, cabbage, and marrow seeds, found that extending the storage period from 8 to 12 months resulted in reduced germination percentages. They noted that these effects may vary among species, suggesting the need for further research on the impact of storage conditions across different species.

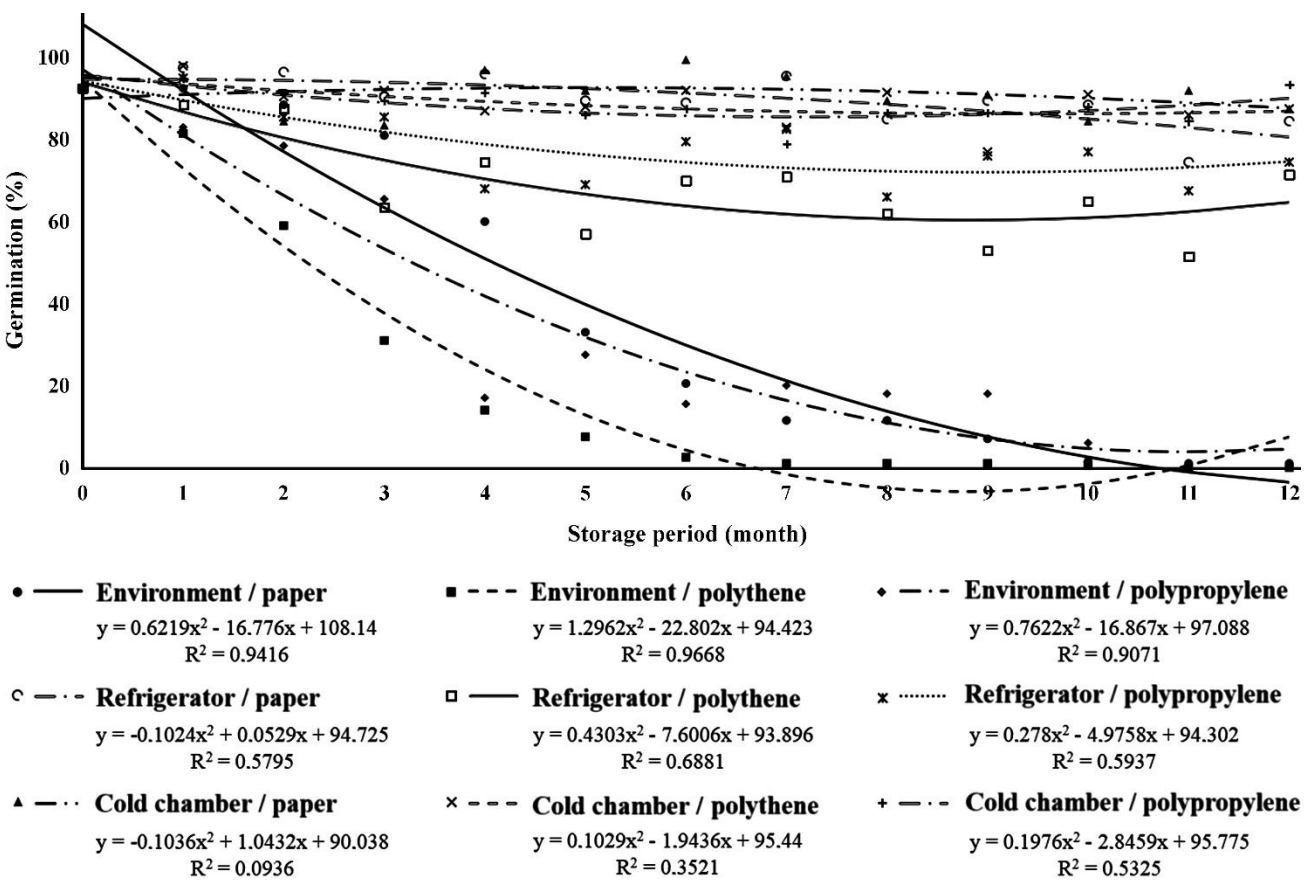

Fig. 1. Germination (%) of pitaya seeds (*Hylocereus undatus*) under different packaging (paper, polythene, and polypropylene) and storage environments (ambient, refrigerator, and cold chamber) over 12 months.

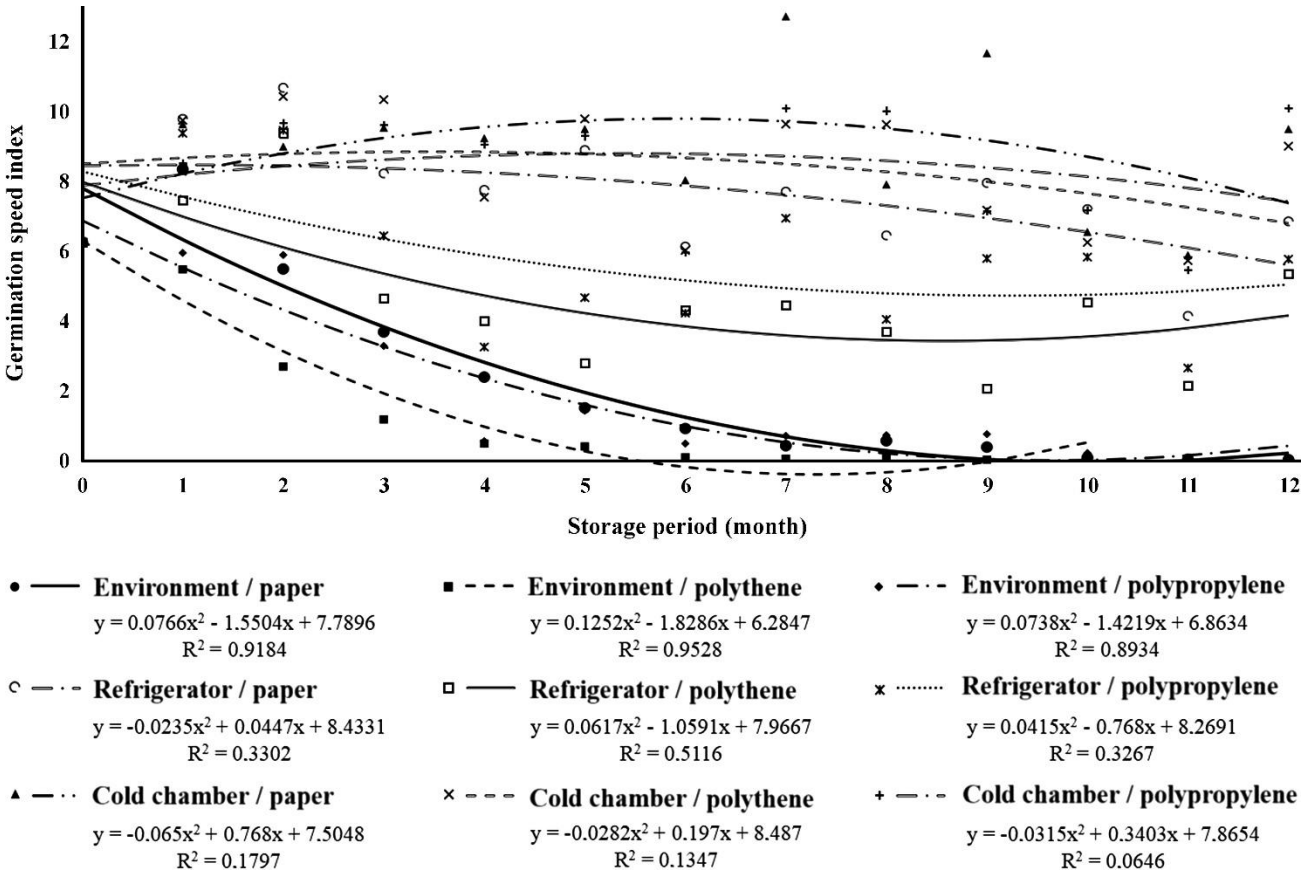

Fig. 2. Germination speed index (GSI) of pitaya seeds (*Hylocereus undatus*) under different packaging (paper, polythene, and polypropylene) and storage environments (ambient, refrigerator, and cold chamber) over 12 months.

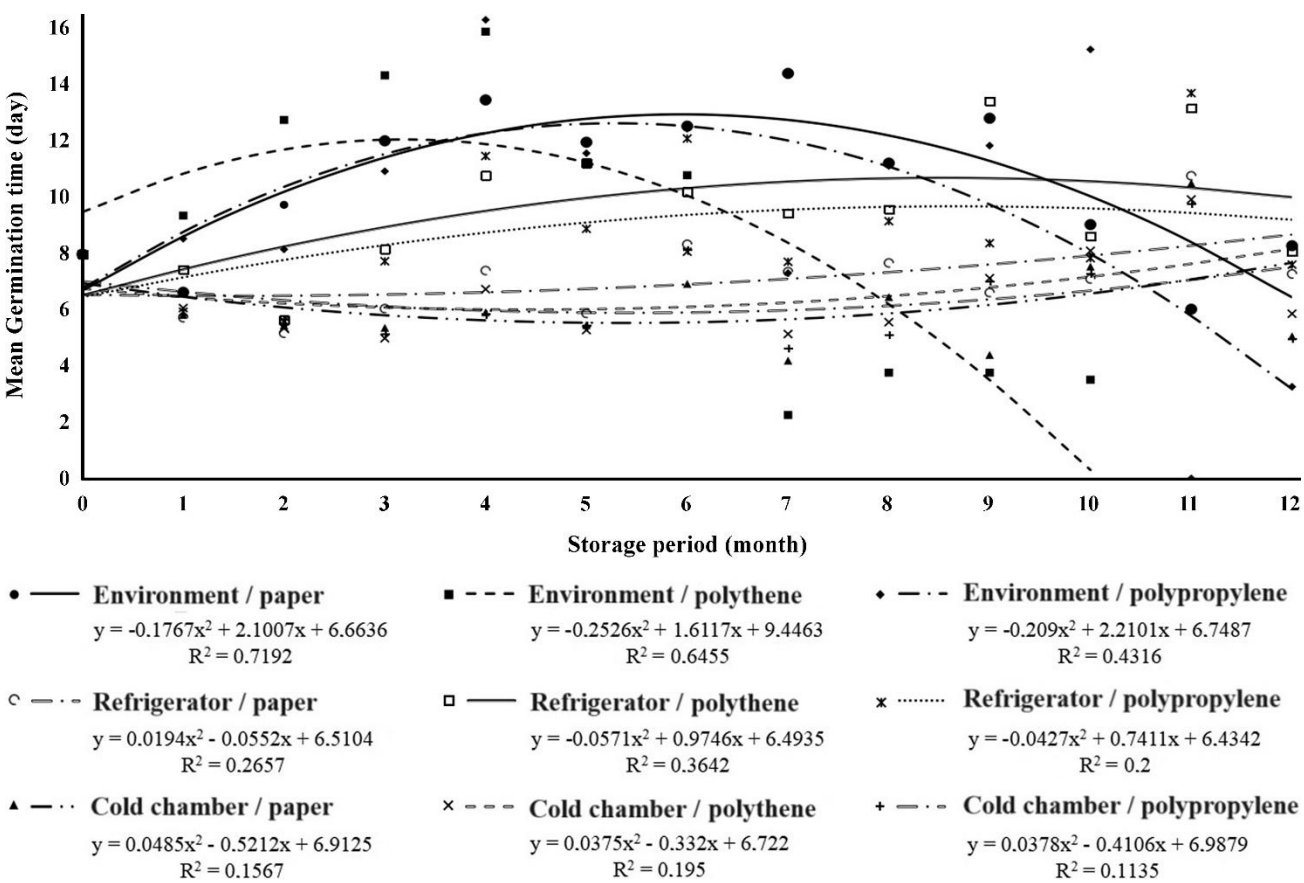

Fig. 3. Mean germination time (MGT - days) of pitaya seeds (*Hylocereus undatus*) under different packaging (paper, polythene, and polypropylene) and storage environments (ambient, refrigerator, and cold chamber) over 12 months.

The cold chamber condition proved to be favorable for reducing MGT in all evaluated packaging types, requiring fewer days to germinate. This minimized the effect of adverse field conditions, as the germination process was advanced by approximately 3 days when comparing the seeds at time zero with those stored for 12 months (Fig. 3).

According to Lamsal & Baributsa (2023), millions of smallholder farmers use airtight (hermetic) storage to preserve commodities. However, depending on the species and intended storage duration, more economically viable packaging options may be available. For pitaya seeds, storage for up to 12 months in paper, polythene, or polypropylene bags maintains seed viability and vigor, as indicated by the germination, GSI, and MGT variables.

Kadam *et al*., (2023) found that polythene bags are effective at creating a moisture barrier, protecting seeds from excess moisture that could lead to rot or fungal growth. They help maintain a relatively stable temperature, essential for seed longevity, and prevent extreme temperature fluctuations that can damage seeds. Additionally, polythene bags are durable and resistant to tearing, ensuring that seeds remain protected during handling and storage compared to cloth and gunny bags.

The study underscores the importance of using paper, polythene, or polypropylene packaging in a cold chamber to preserve the physiological quality of pitaya seeds (*H. undatus*) over 12 months. This technique is not only effective in maintaining seed viability and vigor, but it also offers significant advantages in terms of cost, reproducibility, and safety. Paper and polythene packaging are economically accessible, making them viable options for widespread use, especially in resource-limited settings. Additionally, these methods are easily reproducible, allowing for consistent application across different storage environments. The cold chamber storage further enhances safety by providing a controlled environment that minimizes degradation of seed quality. Therefore, this technique presents a practical and reliable solution for long-term seed conservation, ensuring the genetic integrity and viability of pitaya seeds.

Conclusion

Pitaya seeds (*H. undatus*) stored in a cold chamber maintain their physiological quality in paper, polythene, or polypropylene packaging for up to 12 months. However, under the other storage conditions evaluated, the storage period should be shortened due to their negative impact on the physiological quality of pitaya seeds.

References

Anagha, P.K., D.P. Prakasha, H. Kulapati, A. Mallikarjun, M. Vijay and N. Anand. 2024. Improving seed germination and seedling growth of dragon fruit (*Hylocereus undatus*) by PGRs. *Ind. J. Agric. Sci.*, 94(2): 187-191. doi: 10.56093/ijas.v94i2.140708.

Assaye, Y.M. and H.A. Alemayehu. 2023. Evaluation of different seed packaging materials for quality of rice seed stored for different periods of time in Ethiopia. *J. Pack. Technol. Res*., 7: 55-61. doi: 10.1007/s41783-022-00150-7.

Dadlani, M. and D.K. Yadava (Eds.). 2023. Seed science and technology: Biology, production, quality. Springer, Singapore.

Dahanayake, N. and A.L. Ranawake. 2011. Regeneration of dragon fruit (*Hylecereus undatus*) plantlets from leaf and stem explants. *Trop. Agric. Res. Ext*., 14(4).

Demir, I. and N. Kadioğlu. 2024. The effects of oxygen availability in the seed container during storage on seed germination in tomato, onion, cabbage, and marrow seeds. *Hortis*., 41(1): 1-5. doi: 10.16882/HortiS.1403403.

Kadam, L.S., M.R. Meshram, V.B. Jadhav and S.K. Ransing. 2023. Effect of containers and storage conditions on germination of wheat seed. *Pharma Innov*., 12(10): 323-326.

Lamsal, G. and D. Baributsa. 2023. Enhancing airtight storage with germinating cowpea seeds: impacts on insect mortality, progeny and grain quality. *Insects*., 14(954): 1-13. doi: 10.3390/insects14120954.

Lima, J.D., C.C. Almeida, V.A.V. Dantas, B.M.S. Silva and W.S. Moraes. 2006. Efeito da temperatura e do substrato na germinação de sementes de *Caesalpinia ferrea* Mart. ex Tul. (Leguminosae, Caesalpinoideae). *Rev. Árvore*., 30(4): 513-518. doi: 10.1590/S0100-67622006000400003.

Maguire, J.D. 1962. Speed of germination—Aid in selection and evaluation for seedling emergence and vigor. *Crop Sci*., 2(2): 176-177. doi: 10.2135/cropsci1962.0011183X000200020033x.

Pasko, P., A. Galanty, P. Zagrodzki, Y.G. Ku, P. Luksirikul, M. Weisz and S. Gorinstein. 2021. Bioactivity and cytotoxicity of different species of pitaya fruits – A comparative study with advanced chemometric analysis. *Food Biosci*., 40: 100888. doi: 10.1016/j.fbio.2021.100888.

Rehmani, M.S., B. Xian, S. Wei, J. He, Z. Feng, H. Huang and K. Shu. 2023. Seedling establishment: The neglected trait in the seed longevity field. *Plant Physiol. Biochem*., 200: 107765. doi: 10.1016/j.plaphy.2023.107765.

Roriz, C.L., S.A. Heleno, M.J. Alves, M.B.P.P. Oliveira, J. Pinela, M.I. Dias, R.C. Calhelha, P. Morales, I.C.F.R. Ferreira and L. Barros. 2022. Red pitaya (*Hylocereus costaricensis*) peel as a source of valuable molecules: extraction optimization to recover natural coloring agents. *Food Chem*., 15(372): 131344. doi: 10.1016/j.foodchem.2021.131344.

Vishnupriya, J., S.P. Thamaraiselvi, K. Hemaprabha and C. Kavitha. 2019. Influence of growth regulators on *In vitro* seed germination of dragon fruit (*Hylocereus undatus*). *Int. J. Chem. Stud*., 7(3): 3313-3315.