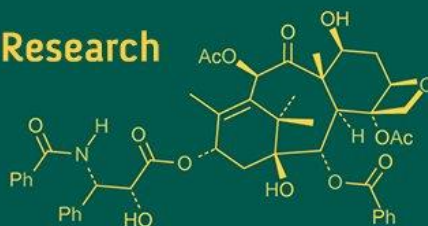


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Influence of storage period and storage container on seed quality attributes of cashew seed nuts (*Anacardium occidentale* L.)

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Abstract

An investigation was conducted at RHREC, Kumbapur farm, Dharwad, during 2025-26 to assess the influence of storage period and storage containers on the seed quality attributes of cashew (cv. Vengurla-4) seed nuts. Seed nuts were stored under ambient conditions in three containers, viz., cloth bag (C₁: control), 700-gauge polythene bag (C₂) and poly-lined gunny bag (C₃), for nine months, with seed quality assessed at monthly intervals. The experiment was conducted in a Factorial Completely Randomised Design with three replications. Irrespective of storage containers, germination decreased from 80.67 to 53.89 percent, Seedling Vigour Index-I (SVI-I) from 2704 to 1536, SVI-II from 733 to 422, shoot length from 19.52 to 17.17 cm, root length from 14.00 to 11.21 cm and seedling dry weight from 9.09 to 7.76 g from one to nine months of storage. Dehydrogenase and peroxidase activities declined from 1.33 to 0.99 OD and 2.39 to 1.02 $\mu\text{mol/cm/min/g}$, respectively. Among the containers, the 700-gauge polythene bag recorded the highest mean for germination (74.78%), SVI-I (2401), SVI-II (667), shoot length (18.61 cm), root length (13.40 cm), dry weight (8.91 g), dehydrogenase activity (1.24 OD) and peroxidase activity (1.91 $\mu\text{mol/cm/min/g}$), whereas the cloth bag recorded the lowest values. The interaction between storage period and container was significant for all traits except shoot length. After nine months, seed nuts stored in 700-gauge polythene bag (S₉C₂) retained the highest germination (58.67%), SVI-I (1742), SVI-II (506), root length (12.37 cm), seedling dry weight (8.63 g), dehydrogenase activity (1.12 OD) and peroxidase activity (1.27 $\mu\text{mol/cm/min/g}$). In contrast, the lowest values (48.33%, 1267, 309, 9.39 cm, 6.40 g, 0.80 OD and 0.58 $\mu\text{mol/cm/min/g}$ respectively) were recorded in cloth bag (S₉C₁). Thus, 700-gauge polythene packaging effectively reduced physiological and biochemical deterioration and better preserved the quality and vigour of cashew seed nuts during prolonged ambient storage.

Keywords: Seed deterioration, seed quality, storage containers, storage period

Introduction

Cashew (*Anacardium occidentale* L.) is an important commercial tree crop of India, contributing significantly to foreign exchange earnings and rural livelihoods along the coastal states. During 2024-25, the crop occupied 12.02 lakh ha area with a production of 7.94 lakh tonnes of raw nuts nationally, and in Karnataka alone covered 1.39 lakh ha, yielding an average productivity of only 0.57 MT ha⁻¹ (Anon, 2024-25) [2]. Despite continuous expansion in area, productivity remains low, and access to healthy, vigorous planting material raised from good-quality seed nuts is a key determinant of successful nursery establishment and orchard productivity.

Seed storage plays a vital role in cashew seed management, since nursery operations depend on seed nuts being available beyond the immediate harvest window. Cashew seeds, however lose viability rapidly after harvest; germination percentage declines steadily even within four to five months of storage (Mandal, 2007) [12]. This deterioration is closely linked to oxidative stress arising from the accumulation of reactive oxygen species, which triggers lipid peroxidation, damages membrane structure, and progressively impairs enzymatic activity and respiratory efficiency within the seed.

The packaging material used for storage strongly influences the rate of this deterioration by regulating moisture and gas exchange around the seed. Containers that restrict moisture entry and limit oxygen movement have been reported to preserve seed viability for longer periods under ambient storage conditions (Pradipkumar, 2012 [13]; Rathod *et al.*, 2016 [17]), whereas.

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porous packaging exposes seeds to continuous moisture fluctuation that accelerates physiological ageing. Selecting a suitable storage container is therefore essential for maintaining the vigour of cashew seed nuts held over extended periods.

Although the individual effects of storage duration and container type on seed viability have been studied in cashew and related tree species, comprehensive evaluations tracking both physiological (germination, vigour indices) and biochemical (enzymatic) markers of deterioration together, across an extended nine-month ambient storage period, remain limited. Such an integrated assessment is necessary to identify a storage container capable of reliably preserving seed quality for cashew nurseries that depend on stored seed nuts for raising rootstocks.

Against this backdrop, the present investigation was undertaken to study the influence of storage period and storage container on the seed quality attributes of cashew seed nuts.

Materials and Methods

The experiment was conducted at the Department of Seed Science and Technology, UAS, Dharwad and RHREC, Kumbapur farm, Dharwad during 2025-26. Fresh cashew seed nuts of cv. Vengurla-4, harvested from 19-year-old trees and dried to 7.1 percent moisture, served as the test material.

The experiment was laid out in a Factorial Completely Randomised Design with two factors and three replications (50 seeds/replication): Factor 1 being storage container (C_1 : cloth bag/control; C_2 : 700-gauge polythene bag; C_3 : poly-lined gunny bag); Factor 2 being storage period (S_1 to S_9 : first to ninth month after storage). Packed seed nuts were kept under ambient conditions for nine months (June 2025-March 2026), with samples drawn monthly for evaluation.

Germination (%) was recorded at 30 days after sowing the seed nuts in polythene bags. Seedling root and shoot length (cm) was measured at 30 days after sowing by randomly selecting five seedlings from each treatment and recording the length from the collar region to the root tip and shoot tip respectively and the average was expressed in centimetres. Seedling vigour index-I (germination% $\times$ total seedling length) and seedling vigour index-II (germination% $\times$ seedling dry weight) were computed following Abdul Baki and Anderson 1973^[1], using seedling measurements (5 seedlings/replication, oven-dried at 80 °C for 24 h for dry weight).

Total dehydrogenase activity was assessed by the tetrazolium (TTC) staining method (Kittoch and Law, 1968)^[11], with absorbance recorded at 470 nm. Peroxidase activity was assayed following Castillo *et al.* (1994)^[4], based on the oxidation of guaiacol to tetraguaiacol, measured at 470 nm and expressed as $\mu\text{mol}/\text{cm}/\text{min}/\text{g}$ fresh weight. Biochemical parameters were analysed at initial, mid (5th month) and final (9th month) storage period. Data were analysed statistically for FCRD, with critical difference computed at 1 percent level (Gomez and Gomez, 1984)^[8].

Results and Discussion

Seed germination declined progressively with advancing storage period (Table 1). Irrespective of container, mean germination declined from 80.67 percent at one month (S_1) to 53.89 percent after nine months (S_9), an overall decline of 33.2 percent. Among containers, the 700-gauge polythene

bag (C_2) recorded the highest mean germination (74.78%), followed by the poly-lined gunny bag (C_3 : 72.74%), while the cloth bag (C_1) recorded the lowest (66.89%). The storage period and container interaction was significant. At the end of storage period, the highest germination (58.67%) was recorded in seed nuts stored in 700-gauge polythene bag (S_9C_2) and the lowest (48.33%) in S_9C_1 . The rate of decline over nine months was sharpest in the cloth bag (39.59% loss) compared to the poly-lined gunny bag (31.94%) and the 700-gauge polythene bag (28.16%), indicating that low-permeability packaging substantially slowed physiological ageing by restricting moisture and gas exchange (Doijode, 2001^[7]; Justice and Bass, 1978^[9]). Similar container-dependent protection of viability has been reported by Rao *et al.* (1957)^[16] in cashew and by Dalal *et al.* (2025)^[5] in Rohida seeds.

Shoot and root length followed a similar declining trend with storage duration (Table 2 and 3), from (19.52 cm and 14.00 cm, respectively) after one month (S_1) to (17.17 cm and 11.21 cm, respectively) after ninth month (S_9). Among containers, C_2 performed best (18.61 cm and 13.40 cm) with C_1 recording the lowest (17.84 cm and 11.78 cm). The interaction between storage period and container was significant for root length. At the end of ninth month of storage, the highest value (12.37 cm) was recorded in seed nuts stored in 700-gauge polythene bag (S_9C_2), while the lowest (9.39 cm) recorded in cloth bag (S_9C_1). Shoot and root elongation depend on the seed nut's moisture status and how efficiently stored cotyledonary reserves are mobilized to the growing meristems at sowing. The low-permeability polythene bag retained more internal moisture, slowing reserve depletion and sustaining plumule and radicle growth even after prolonged storage. In contrast, the porous cloth bag allowed continuous moisture fluctuation, hastening reserve depletion and reducing seedling elongation. These findings align with Rathod *et al.* (2016)^[17], who recorded the maximum shoot length and root length of cashew seedlings raised from seed nuts stored in poly-lined gunny bag, and with Prakashbhai (2020)^[14], who reported the maximum shoot length and root length at 90 days after sowing with seeds packed in polybag, at par with gunny bag but significantly superior to open storage.

Seedling dry weight also declined progressively with advancing storage period (Table 4). Irrespective of storage container, the mean dry weight decreased from 9.09 g after one month (S_1) to 7.76 g after nine months (S_9). Among storage containers, the 700-gauge polythene bag (C_2) recorded the highest mean dry weight (8.91 g), followed by the poly-lined gunny bag (C_3 : 8.61 g), while the cloth bag (C_1) recorded the lowest (7.72 g). The interaction between storage period and container was significant. At the end of ninth month, the highest dry weight (8.63 g) recorded in seed nuts stored 700-gauge polythene bag (S_9C_2) which was statistically on par with seed nuts stored poly-lined gunny bag (S_9C_3) (8.26 g), whereas the lowest value (6.40 g) was recorded in cloth bag (S_9C_1). The higher dry weight under low-permeability packaging may be attributed to better retention of seed moisture and metabolic activity, supporting more uniform germination, reserve mobilization and subsequent seedling biomass accumulation. The present trend is in agreement with Rathod *et al.* (2016)^[17], who reported higher dry weight of cashew seedlings from seed nuts stored in poly-lined gunny bags, and Prakashbhai (2020)^[14], who reported maximum dry weight with seeds

packed in polybag, at par with gunny bag but superior to open storage.

Seedling vigour indices, being composite traits derived from germination and seedling growth or dry weight, declined progressively with advancing storage period, following the same overall pattern as germination (Tables 5 and 6). For Seedling vigour index-I, the overall mean declined from 2704 at one month (S₁) to 1536 after nine months (S₉), a decline of 43.2 percent. Among containers, the 700-gauge polythene bag (C₂) recorded the highest mean (2401), followed by the poly-lined gunny bag (C₃: 2320), while the cloth bag (C₁) recorded the lowest (2008). The interaction was significant, the highest value (1742) was recorded in S₉C₂, and the lowest (1267) in S₉C₁ at the end of ninth month of storage; over nine months the cloth bag lost 52.0 percent of its vigour index-I value, against 37.0 percent in the 700-gauge polythene bag and 41.0 percent in the poly-lined gunny bag. Seedling vigour index-II followed a closely comparable trend, the overall mean fell from 733 at first month (S₁) to 422 after ninth month (S₉), a decline of 42.4 percent. Among containers, 700-gauge polythene bag recorded the highest mean (667) and the cloth bag recorded the lowest (529). The interaction was significant, the highest value (506) recorded in S₉C₂ and the lowest (309) in S₉C₁ at the end of storage period; the cloth bag recorded the sharpest decline (57.0%), compared with 32.5 percent in the 700-gauge polythene bag and 38.3 percent in the poly-lined gunny bag. Since these indices are products rather than sums of their components, even a moderate simultaneous decline in germination and seedling growth compounded substantially over the storage period, explaining the sharp reduction observed in cloth-bag-stored seed after nine months. Comparable declines in vigour indices with prolonged storage have been reported in karonda by Kaur and Kaur (2019)^[10] and in aonla by Purbey *et al.* (2018)^[15]. Both dehydrogenase and peroxidase activities declined steadily with advancing storage, with a significant storage period and container interaction confirming a faster decline in the poorly protective cloth bag (Fig. 1 and 2). Dehydrogenase activity, uniform at 1.33 OD across all containers before storage (S₀), fell to 0.80 OD in the cloth bag by the end of ninth month (S₉, a loss of 39.8%), compared with 1.12 OD in the 700-gauge polythene bag (15.8% loss) and 1.05 OD in the poly-lined gunny bag (21.1% loss); among the storage container, mean activity was highest in the 700-gauge polythene bag (1.24 OD) and lowest in the cloth bag (1.06 OD). Peroxidase activity showed an even sharper decline, falling from a uniform initial value of 2.39 $\mu\text{mol/cm/min/g}$ to 0.58 $\mu\text{mol/cm/min/g}$ in the cloth bag by the end of ninth month (a loss of 75.7%), against 1.27 $\mu\text{mol/cm/min/g}$ in the 700-gauge polythene bag (46.9% loss) and 1.02 $\mu\text{mol/cm/min/g}$ in the poly-lined gunny bag (57.3% loss); mean peroxidase activity was highest in the 700-gauge polythene bag (1.91 $\mu\text{mol/cm/min/g}$) and lowest in the cloth bag (1.32 $\mu\text{mol/cm/min/g}$). Dehydrogenase activity reflects the respiratory vigour of living seed tissue, and its higher retention in low-permeability packaging indicates slower depletion of respiratory capacity; similarly, better-maintained peroxidase activity points to a more functional antioxidant system, limiting oxidative damage from reactive oxygen species during storage. These findings align with Bhanuprakash *et al.* (2010)^[3] in bell pepper and Demirkaya

et al. (2010)^[6] in onion, both of which reported a decline in these enzyme activities with advancing seed age.

Table 1: Influence of storage period and storage container on seed germination (%) of cashew seed nuts

Storage period	Storage containers			Mean
	C ₁	C ₂	C ₃	
S ₁	80.00 (63.44)	*81.67 (64.44)	80.33 (63.69)	80.67 (63.93)
S ₂	79.00 (62.73)	81.33 (64.41)	79.67 (63.20)	80.00 (63.45)
S ₃	77.00 (61.35)	81.33 (64.41)	80.67 (63.94)	79.67 (63.23)
S ₄	73.67 (59.13)	79.67 (63.20)	78.33 (62.27)	77.22 (61.53)
S ₅	69.67 (56.59)	79.33 (62.97)	78.67 (62.53)	75.89 (60.70)
S ₆	64.67 (53.53)	72.33 (58.27)	69.00 (56.17)	68.67 (55.99)
S ₇	59.00 (50.19)	71.00 (57.42)	68.67 (55.96)	66.22 (54.52)
S ₈	50.67 (45.38)	67.67 (55.35)	64.67 (53.53)	61.00 (51.42)
S ₉	48.33 (44.04)	58.67 (49.99)	54.67 (47.68)	53.89 (47.24)
Mean	66.89 (55.15)	74.78 (60.08)	72.74 (58.77)	71.47 (58.00)
	S	C	S X C	
S.Em±	0.31	0.18	0.54	
CD at 1%	1.20	0.69	2.07	

*Figures in parenthesis indicate arcsine transformed values. C₁-Cloth bag (control); C₂-700-gauge polythene bag; C₃-Poly-lined gunny bag; S₁-S₉-first to ninth month after storage.

Table 2: Influence of storage period and storage container on shoot length (cm) of cashew seed nuts

Storage period	Storage containers			Mean
	C ₁	C ₂	C ₃	
S ₁	19.02	19.82	19.72	19.52
S ₂	18.51	19.09	18.93	18.84
S ₃	18.61	19.09	18.87	18.86
S ₄	18.34	19.05	19.09	18.83
S ₅	17.82	18.38	18.34	18.18
S ₆	17.24	18.25	18.23	17.91
S ₇	17.12	18.21	17.96	17.77
S ₈	17.07	18.26	17.72	17.68
S ₉	16.84	17.34	17.33	17.17
Mean	17.84	18.61	18.47	18.31
	S	C	S X C	
S.Em±	0.08	0.05	0.14	
CD at 1%	0.30	0.17	NS	

C₁-Cloth bag (control); C₂-700-gauge polythene bag; C₃-Poly-lined gunny bag; S₁-S₉-first to ninth month after storage.

Table 3: Influence of storage period and storage container on root length (cm) of cashew seed nuts

Storage period	Storage containers			Mean
	C ₁	C ₂	C ₃	
S ₁	13.95	14.06	13.99	14.00
S ₂	13.69	13.98	13.95	13.87
S ₃	13.65	13.93	13.88	13.82
S ₄	13.05	13.82	13.35	13.41
S ₅	11.47	13.24	13.24	12.65
S ₆	10.81	13.02	13.26	12.36
S ₇	10.22	13.33	13.12	12.22
S ₈	9.81	12.82	12.94	11.86
S ₉	9.39	12.37	11.88	11.21
Mean	11.78	13.40	13.29	12.82
	S	C	S X C	
S.Em±	0.07	0.04	0.13	
CD at 1%	0.27	0.16	0.47	

C₁-Cloth bag (control); C₂-700-gauge polythene bag; C₃-Poly-lined gunny bag; S₁-S₉-first to ninth month after storage.

Table 4: Influence of storage period and storage container on seedling dry weight (g) of cashew seed nuts

Storage period	Storage containers			Mean
	C ₁	C ₂	C ₃	
S ₁	8.99	9.19	9.10	9.09
S ₂	8.88	9.11	8.98	8.99
S ₃	8.75	9.06	8.69	8.84
S ₄	8.77	9.08	8.68	8.84
S ₅	7.55	8.90	8.51	8.32
S ₆	7.02	8.90	8.51	8.14
S ₇	6.48	8.69	8.37	7.85
S ₈	6.65	8.63	8.38	7.89
S ₉	6.40	8.63	8.26	7.76
Mean	7.72	8.91	8.61	8.41
	S	C	S X C	
S.Em (±)	0.07	0.04	0.12	
CD at 1%	0.26	0.15	0.45	

C₁-Cloth bag (control); C₂-700-gauge polythene bag; C₃-Poly-lined gunny bag; S₁-S₉-first to ninth month after storage.

Table 5: Influence of storage period and storage container on seedling vigour index-I of cashew seed nuts

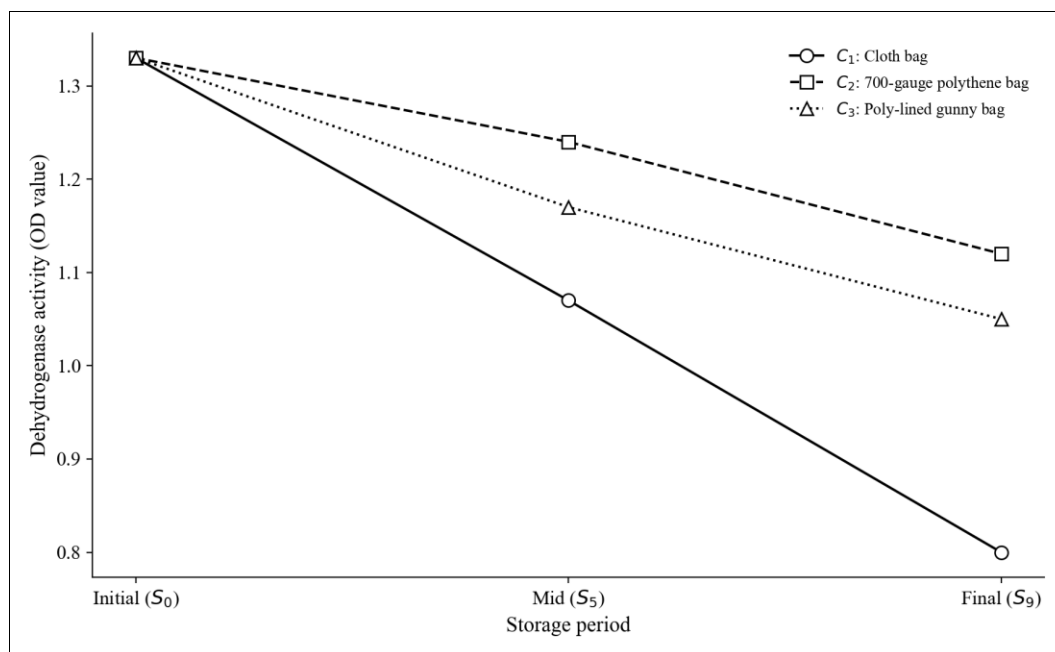
Storage period	Storage containers			Mean
	C ₁	C ₂	C ₃	
S ₁	2637	2766	2708	2704
S ₂	2543	2690	2620	2617
S ₃	2483	2685	2642	2603
S ₄	2312	2619	2541	2491
S ₅	2041	2508	2485	2344
S ₆	1814	2261	2172	2082
S ₇	1613	2239	2134	1995
S ₈	1361	2103	1982	1815
S ₉	1267	1742	1597	1536
Mean	2008	2401	2320	2243
	S	C	S X C	
S.Em±	17.38	10.03	30.10	
CD at 1%	65.62	37.89	113.66	

C₁-Cloth bag (control); C₂-700-gauge polythene bag; C₃-Poly-lined gunny bag; S₁-S₉-first to ninth month after storage.

Table 6: Influence of storage period and storage container on seedling vigour index-II of cashew seed nuts

Storage period	Storage containers			Mean
	C ₁	C ₂	C ₃	
S ₁	719	750	731	733
S ₂	701	740	715	719
S ₃	674	737	701	704
S ₄	646	723	680	683
S ₅	526	705	669	633
S ₆	453	643	587	561
S ₇	395	617	575	529
S ₈	336	583	542	487
S ₉	309	506	451	422
Mean	529	667	628	608
	S	C	S X C	
S.Em±	6.71	3.87	11.63	
CD at 1%	25.36	14.64	43.93	

C₁-Cloth bag (control); C₂-700-gauge polythene bag; C₃-Poly-lined gunny bag; S₁-S₉-first to ninth month after storage.

**Fig 1:** Influence of storage period and storage container on total dehydrogenase activity of cashew seed nuts

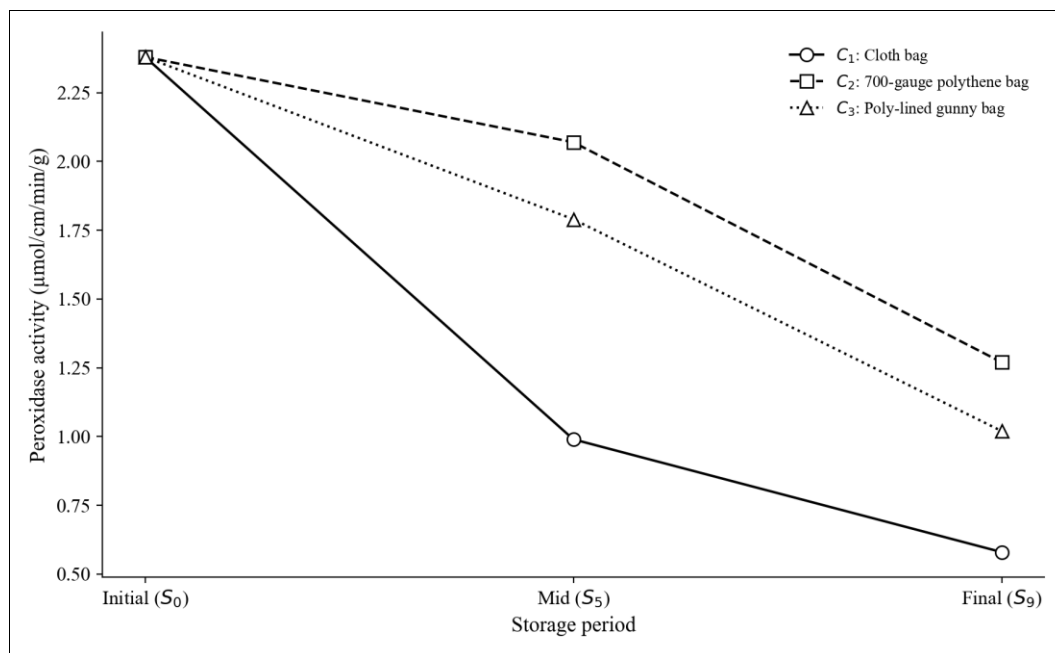


Fig 2: Influence of storage period and storage container on peroxidase activity of cashew seed nuts

Conclusion

Seed quality attributes of cashew seed nuts declined progressively with advancing storage period under ambient conditions, but the rate of deterioration was strongly influenced by the storage container used. The 700-gauge polythene bag was the most effective in preserving germination, seedling vigour and enzymatic activity of stored cashew seed nuts, followed by the poly-lined gunny bag, while the cloth bag recorded the fastest decline. Low-permeability packaging is therefore recommended for maintaining the quality of cashew seed nuts intended for extended ambient storage.

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