RESEARCH ARTICLE Legume Research- An International Journal, Volume 49 Issue 5: 850-855 (May 2026)

Extending Seed Viability in Groundnut (*Arachis hypogaea* L.) under Ultra-dry Moisture and Vacuum Storage

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10.18805/LR-5400

ABSTRACT

Background: The groundnut or peanut seed possess very short viability. Thus, it is usually stored along with pod and at the time of sowing, the seeds are decorticated and used.

Methods: An experiment was conducted to extend the storability of decorticated seeds (kernels) by ultra-dry moisture content and vacuum packing in the Department of Seed Science and Technology, Seed Centre, Tamil Nadu Agricultural University, Coimbatore during 2020-23.

Result: The results showed that the kernels with 5.0% moisture content, vacuum packed and stored at -20°C, -5°C and 5°C have maintained the germination above Indian minimum seed certification standards (IMSCS) *i.e.* more than 70% upto 20 months. However, the kernels with 6.0% moisture content and stored under ambient condition have showed a rapid reduction in germination and recorded 68% in four months storage. Nevertheless, the kernels dried with 3.5% moisture were not able to withstand the moisture loss and recorded reduction in germination at six months period. The seedling vigour was also maintained in the kernels stored at -20°C, -5°C and 5°C with 5.0% seed moisture. Further, histological studies indicated that the seeds dried to 5.0% moisture content and stored at low temperature had intact seed coat and cells whereas, they were damaged when the seeds dried to 3.5% moisture content. Hence, because of better viability, reduced space required for storage and easy to transport, conservation of kernels would be highly cost-effective under the controlled environmental conditions, as compared to pod storage.

Key words: Groundnut, Seed germination, Seed storage, Ultra-dry moisture, Vacuum bag.

INTRODUCTION

Groundnut or peanut (*Arachis hypogaea* L.) is an important leguminous oilseed crop commonly called as 'poor man's nut' widely cultivated in the tropical and sub-tropical conditions. It is the third most vital vegetable protein source in the world and fourth important source of edible oil crop. India is the leading country in groundnut cultivation and ranks first in area and second in production in the world. Besides high oil content, the crop is valued for its edible seeds. During 2021-22, 101 lakh tonnes was produced in India with the productivity of 1863 kg ha^{-1} (agricoop.nic.in). Quick loss in seed viability during storage is an important issue in groundnut seed production. In which, the seeds deteriorate rapidly due to accumulation of specific iso-esterases during ageing process (Aung and McDonald, 1995). Therefore, the availability of quality seed at the time of sowing is a common problem in groundnut cultivation.

The longevity of seed is mainly depends on the amount of water it contains and the temperature in which it is stored. In general, the lower the moisture content, the longer the viability. Seed longevity is doubled for every one per cent decrease in seed moisture content or 5°C decrease in temperature. Therefore, seed storage life can be enhanced considerably by lowering both moisture and temperature. However, moisture content is the key factor that can be lowered for successful seed storage.

Ultra-dry storage, also called low moisture content storage, is a technique for decreasing seed moisture content to below 5-6 per cent using different methods and then storing hermetically at ambient, but preferably lower temperatures. Some studies have confirmed that low moisture content storage can not only be used to maintain the quality of seeds, but also improve their storability (Li *et al.,* 2008). Further, ultra-dry seed storage at ambient temperature not only improves their longevity and vigour but also assures to be a cost-effective technique for germplasm conservation (Guang-Hua *et al.,* 1998). For example, soybean seed deterioration can be decreased at ambient temperature by the ultra-dry treatment compared to non-ultra-dry wherein, the deterioration was higher during storage at room temperature than cold room (Ali *et al.,* 2020).

The ability of seeds to withstand severe desiccation is reliant on the drying rate, which has been revealed to affect seed survival after drying (Bailly *et al.,* 2001). Li and An (2006) opined that the water content of seed is a key factor

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How to cite this article: Raja, K. (2026). Extending Seed Viability in Groundnut (*Arachis hypogaea* L.) under Ultra-dry Moisture and Vacuum Storage. *Legume Research*. **49(5):** 850-855. doi: 10.18805/LR-5400.

Submitted: 14-08-2024 **Accepted:** 09-02-2025 **Online:** 31-03-2025

for storage at ambient temperature and 3.5% seem to be the best water content for ultra-dry seeds in *Ammopiptanthus mongolicus*. Ultra-dry seeds with a moisture content of 3.9% can be effectively used to preserve *Handeliondendron bodinieri* seeds at low temperature storage for enhanced seed vigour, seedling growth and development (Xie *et al.,* 2021). Similarly, Perez *et al.* (2007) found that the seed preservation through silica gel and low temperature *i.e.* -5C^{o} and -10^{o}C has proved highly efficient for Brassicaceae. Since the groundnut seed possess very poor storability, it can be stored for the period of upto 6-8 months. This creates the problems in seed supply, field stand and germplasm conservation. Therefore, the present study was conducted to extend the storability of the seeds by ultra-dry method.

MATERIALS AND METHODS

The experiment was conducted in the Department of Seed Science and Technology, Seed Centre, Tamil Nadu Agricultural University, Coimbatore, India during 2020-23. The freshly harvested groundnut var. CO 6 pods were collected and decorticated for seed (kernel) storage. The kernels were thoroughly cleaned and graded for uniformity in size. Then, the kernels were dried to different moisture contents *viz.*, 3.5, 5.0 and 6.0% by using zeolite beads. During which, the 200 g zeolite beads were put in the bottom of the desiccator for one kilogram of kernels and placed a wire mesh on it. Then, the kernels filled in porous bag were placed on the wire mesh by avoiding direct contact with beads and the desiccator was closed air tight by applying vaseline. The kernel samples were drawn once in two days for the assessment of moisture content. Also, the kernels placed in the desiccator were turned regularly during sampling for uniform drying of moisture and closed immediately. After attainment of required moisture contents, the dried kernels were vacuum packed in aluminium foil pouches and stored at four different temperatures *viz.*, -20^{o}C, -5^{o}C, 5^{o}C and ambient condition.

The stored kernels were evaluated for its viability and vigour at bimonthly intervals by drawing the samples stored at different temperatures. The germination test of this seeds was conducted by placing 400 seeds in four replications with 100 seeds each in sterilized sand medium (ISTA, 2013) and evaluated on final count day *i.e.* on 10th day. Seedling length was measured in randomly selected ten seedlings during the evaluation of the germination test. The vigour index was calculated by multiplying the germination percentage and seedling length (Abdul-Baki and Anderson, 1973).

Electrical conductivity of seed leachate was measured in the seeds placed for storage (Presley, 1958). In addition, Scanning Electron Microscopy (SEM) images of the kernels stored with different moisture contents at various temperatures were taken by using the SEM image analyzer (Model: FEI QUANTA 250) at the laboratory hub of the Department of Nano Science and Technology, Tamil Nadu Agricultural University, Coimbatore for examining anatomy of the seeds.

The data collected were subjected to statistical analysis and the critical difference values were calculated at 5 per cent probability level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Seed storage is one of the major constraints in groundnut because of the presence of high oil in the seeds which ranges from 40 to 56% (Dean *et al.,* 2009). Also, it comprises of about 80% unsaturated fatty acids and 20% saturated fatty acids. In case of unsaturated fatty acids, 42% is constituted by mono unsaturated fatty acids, *i.e.*, oleic acid whereas, 37% by poly unsaturated fatty acids, *i.e.*, linoleic acid (Wang *et al.,* 2015). Thus, the groundnut with high linoleic acid is susceptible to oxidation, leading to unpleasant smell, taste and short shelf life. In addition, the thin and delicate seed coat in groundnut leads to little protection from mechanical damage and slight protrusion of the radicle tip makes the seed vulnerable to damage. Thus, the groundnut seeds are stored along with the shell *i.e.* pods are stored as such with the seeds to protect from external factors (Navarro *et al.,* 1989). In which, in-shell seeds are better protected from mechanical injuries during handling and invasion of moulds and fungi during storage. Nevertheless, pod storage requires more storage space and also expensive compared to shelled seeds especially when the pods stored under controlled conditions of temperature and relative humidity. Conversely, controlling the deterioration is a major task in the shelled seeds because the seeds are much more sensitive to external environments that cause loss of quality. Also, it is important to perceive better methods and techniques to improve the shelf-life of the shelled seeds by controlling the conditions and environments that cause quality deterioration.

Thus, the results from the present study revealed that the germination of groundnut kernels were significantly influenced by moisture contents and storage temperatures. In general, the kernels have recorded decline in germination during storage in irrespective of the seed moisture content and storage temperature. However, kernels with 5.0% moisture content, vacuum packed and stored at -20^{o}C, -5^{o}C and 5^{o}C have maintained the germination above Indian Minimum Seed Certification Standards (>70%) for the period upto 20 months when compared with other treatments (Table 1). Further, the 5.0% moisture content kernels stored at -20^{o}C and -5^{o}C would have maintained the 70% germination upto 24 months. However, the kernels with 5.0% moisture content and stored at ambient condition have maintained the required germination (72%) for the period of 6 months and thereafter, hasty reduction was recorded. Similarly, kernels with 6.0% moisture content and stored under ambient condition have showed analogous reduction in germination and recorded 68% in four months storage. But, requisite germination (70%) in 6.0% moist kernels was recorded when they were stored at -20^{o}C and -5^{o}C. Conversely, the kernels dried with 3.5% moisture content were not able to withstand the

Table 1: Effect of different storage temperature and moisture content on seed germination in groundnut.

Treatments	Germination (%)													
	Initial	2 MAS	4 MAS	6 MAS	8 MAS	10 MAS	12 MAS	14 MAS	16 MAS	18 MAS	20 MAS	22 MAS	24 MAS	Mean
M_1T_0 - 3.5% SMC; Ambient	88	73	68	66	66	60	57	57	55	48	45	45	39	57
M_1T_1 - 3.5% SMC; 5°C	88	75	75	69	67	65	62	59	59	50	42	42	42	59
M_1T_2 - 3.5% SMC; -5°C	88	75	73	73	64	64	64	60	60	60	57	53	52	63
M_1T_3 - 3.5% SMC; -20°C	88	72	70	68	68	67	62	59	59	58	54	57	41	61
M_2T_0 - 5.0% SMC; Ambient	89	86	74	72	66	48	44	44	42	38	21	17	8	47
M_2T_1 - 5.0% SMC; 5°C	89	86	82	82	78	78	78	78	77	76	74	65	62	76
M_2T_2 - 5.0% SMC; -5°C	89	84	83	79	78	77	77	77	77	77	77	70	70	77
M_2T_3 - 5.0% SMC; -20°C	89	89	88	85	84	83	80	80	79	79	77	70	70	80
M_3T_0 - 6.0% SMC; Ambient	89	82	68	9	9	0	0	0	0	0	0	0	0	14
M_3T_1 - 6.0% SMC; 5°C	89	86	84	73	73	69	69	68	68	65	63	56	53	69
M_3T_2 - 6.0% SMC; -5°C	89	81	81	75	75	74	70	66	65	60	58	51	49	67
M_3T_3 - 6.0% SMC; -20°C	89	87	80	74	74	73	70	67	67	66	65	65	43	69
Mean	89	81	77	69	67	63	61	59	59	56	53	49	44	61
			T	**M**	**T×M**									
SEd			1.3	1.3	4.6									
CD (P=0.05)			2.6	2.6	9.3									

*Values in the parenthesis indicate the arc sine values; T- Treatments, M- Months of storage.

moisture loss and recorded rapid reduction in germination below IMSCS even at four to six months period. Similar results of greater loss in viability in seeds conditioned to very low moisture contents were reported earlier (Jain *et al.,* 2016). Correspondingly, Rao *et al.* (2002) studied that groundnut seeds hermetically stored at room temperature (23-25°C) with low moisture content (3.6-4%) could retain high germination. Under cold room condition, seed quality differences in groundnut cultivars were minimal and maintained high quality up to 6 months when compared with ambient condition (Phyo *et al.,* 2004). Nathalia *et al.* (2020) reported that increasing the water content in groundnut seed reduces the germinative potential and thus, storage of seeds in polyethylene terephthalate packaging with 8% water content showed better results for preserving the seeds. Therefore, groundnut seed quality can be influenced mainly by storage conditions, temperature and relative humidity besides the pest and disease incidence. Desheva (2016) predicted the time of safe storage for peanuts and it was 10 to 20 years for long-term storage conditions with low moisture content of 5±2% in hermetically closed containers at -18°C. Similarly, Hong *et al.* (2005) found that the sub-zero storage temperature helped to maintain the long-term storability of the groundnut seeds in laminated aluminium foil packets. In another study, it was found that the groundnut seeds dried up to 4% moisture content with secondary refrigeration (15°C and 15% RH) retain viability considerably for longer periods and replacing air with vacuum further enhanced seed longevity (Sastry *et al.,* 2007). Ramanadane *et al.* (2025) found that kernel storage in groundnut is possible if kernels are pre-treated with double spectrum fungicide and stored in super grain bags or HDPE bags. Further, soybean, a problematic seed, could be stored for a period of eight months with better germination and vigour with seed treatment of wood ash @ 5 g/kg in aluminium foil container (Vaghasiya *et al.,* 2025), which showed that the aluminium foil storage has better storage life as recorded in the present study.

Similarly, the vigour was reduced with the increase in the storage period irrespective of the seed moisture content and storage temperature. However, the reduction was lesser in the kernels stored at -20°C, -5°C and 5°C with 5.0% seed moisture content (Table 2). The kernels stored at ambient condition with higher moisture have recorded fast reduction in seed vigour due to rapid deterioration. Therefore, the kernels with optimum moisture content of 5.0% have potential to store at lower temperatures. The higher moisture as well as oil in the seed poses the issue of rapid lipid peroxidation during the deterioration process. Chen *et al.* (2011) found that the ultra-dry storage can improve the storability and membrane permeability along with the increase in the activities of superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD).

Additionally, electrical conductivity of the seed leachate has showed increasing trend with respect to increase in the storage period. In which, the kernels stored with 5.0% moisture content and stored at -20°C, -5°C and 5°C have

Table 2: Effect of different storage temperature and moisture content on vigour index in groundnut.

Treatments	Vigour index													
	Initial	2 MAS	4 MAS	6 MAS	8 MAS	10 MAS	12 MAS	14 MAS	16 MAS	18 MAS	20 MAS	22 MAS	24 MAS	Mean
M_1T_0 - 3.5% SMC; Ambient	3218	2843	1888	1515	1210	1249	1742	1873	1881	1507	1103	1391	1084	1607
M_1T_1 - 3.5% SMC; 5°C	3218	2564	1805	2037	1868	1666	1932	2136	2129	1705	1327	1390	1310	1822
M_1T_2 - 3.5% SMC; -5°C	3218	2790	1885	1945	1852	1599	2106	2068	1955	2010	1710	1696	1721	1944
M_1T_3 - 3.5% SMC; -20°C	3218	2502	1814	1964	1935	1190	1716	2024	2084	1711	1663	1619	1296	1793
M_2T_0 - 5.0% SMC; Ambient	3371	3238	2097	1987	1890	459	1054	1331	1134	973	582	386	134	1272
M_2T_1 - 5.0% SMC; 5°C	3371	3240	2328	2491	2378	2335	2475	2679	2717	2386	2427	2321	1965	2478
M_2T_2 - 5.0% SMC; -5°C	3371	3227	2359	2648	2301	2348	2354	2642	2477	2787	2426	2436	2247	2521
M_2T_3 - 5.0% SMC; -20°C	3371	3359	2558	2813	2727	2732	2531	2744	2516	2749	2433	2170	2408	2645
M_3T_0 - 6.0% SMC; Ambient	3368	2898	1642	149	173	-	-	-	-	-	-	-	-	405
M_3T_1 - 6.0% SMC; 5°C	3368	3013	2280	2110	2116	2149	2164	2423	1986	2041	2003	1882	1505	2139
M_3T_2 - 6.0% SMC; -5°C	3368	3088	2289	2179	2129	2044	2463	1992	2067	2106	1717	1744	1450	2105
M_3T_3 - 6.0% SMC; -20°C	3368	3290	2676	2123	2139	1892	2209	2170	2244	2270	2035	2158	1363	2214
Mean	3319	3004	2135	1996	1893	1788	2068	2189	2108	2022	1766	1745	1499	2017
			T	M	T×M									
SEd			56.2	56.2	194.8									
CD (P=0.05)			111.6	111.6	386.6									

(T - Treatments, M - Months of storage).

Table 3: Effect of different storage temperature and moisture content on electrical conductivity of seed leachate in groundnut.

Treatments	Electrical conductivity (dS/m)													
	Initial	2 MAS	4 MAS	6 MAS	8 MAS	10 MAS	12 MAS	14 MAS	16 MAS	18 MAS	20 MAS	22 MAS	24 MAS	Mean
M_1T_0 - 3.5% SMC; Ambient	256	304	585	628	691	710	642	557	573	597	602	643	723	596
M_1T_1 - 3.5% SMC; 5°C	256	323	636	671	703	674	636	547	577	648	689	710	747	621
M_1T_2 - 3.5% SMC; -5°C	256	350	623	630	634	678	664	580	615	653	671	713	716	618
M_1T_3 - 3.5% SMC; -20°C	256	332	646	725	741	741	717	713	757	776	793	815	809	705
M_2T_0 - 5.0% SMC; Ambient	187	189	619	628	637	634	615	660	728	723	720	756	769	656
M_2T_1 - 5.0% SMC; 5°C	187	190	587	627	689	605	644	566	607	615	637	657	677	591
M_2T_2 - 5.0% SMC; -5°C	187	188	599	609	683	618	609	515	541	553	588	611	623	561
M_2T_3 - 5.0% SMC; -20°C	187	201	493	506	559	592	578	591	582	598	611	618	631	555
M_3T_0 - 6.0% SMC; Ambient	198	324	688	692	662	674	1091	1270	1477	1505	1603	1650	1706	1111
M_3T_1 - 6.0% SMC; 5°C	198	379	563	767	783	711	739	807	846	856	892	898	906	770
M_3T_2 - 6.0% SMC; -5°C	198	295	568	648	680	684	697	761	806	832	878	900	929	731
M_3T_3 - 6.0% SMC; -20°C	198	280	548	705	716	688	616	633	638	702	707	710	775	647
Mean	213	279	596	653	681	667	687	683	728	755	783	807	834	680
			T	M	T×M									
SEd			5.9	5.9	20.1									
CD (P=0.05)			11.8	11.9	41.1									

(T- Treatments, M- Months of storage).

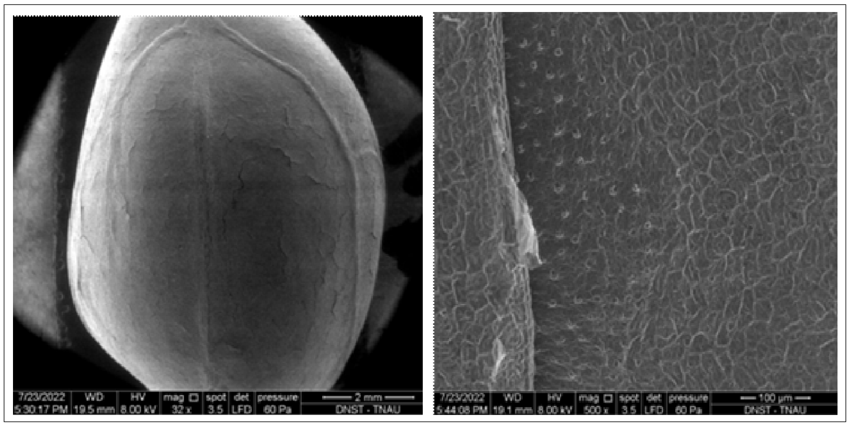

Fig 1: Structural changes in the seed coat and embryonic axis cells (damaged seed coat and cells) of the groundnut kernels dried to 3.5% moisture content.

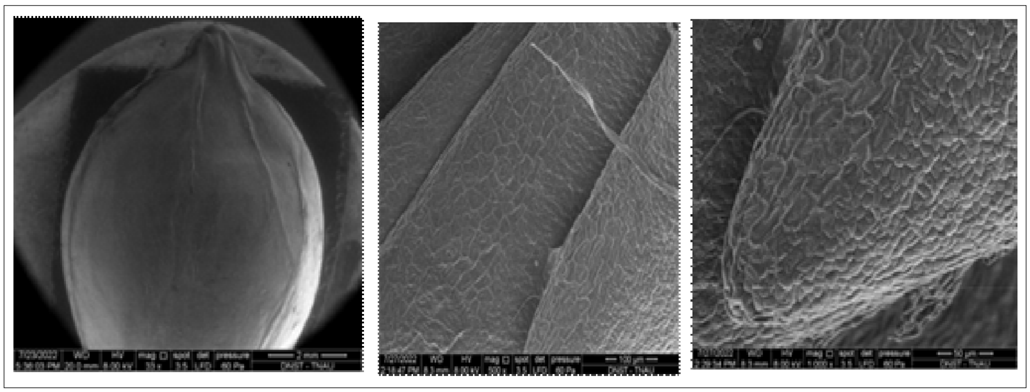

Fig 2: Structures of the seed coat and embryonic axis cells (intact seed coat and cells) of the groundnut kernels dried to 5.0% moisture content.

recorded lesser leachate when compared to other moisture contents and storage temperatures (Table 3). The kernels stored with 6.0% moisture and stored at ambient condition have showed maximum electrical conductivity because of higher leachate of electrolytes from the seed. This might be due to the lipid peroxidative process and further breaking of cell structures which leads to the escape of the cellular constituents into the solutes. Also, the minimum required moisture is essential for functioning of the cellular organelles. In this case, the kernels dried to 3.5% moisture content has recorded with damages in the seed coat and cells of the embryonic axis (Fig 1) which leads to more electrolytes leachate. Also, slightly increased electrolyte leakage was observed initially in the seeds dried to 3.5% moisture content rather 5.0 and 6.0% moisture contents which may be due to cellular damages with more moisture loss. However, the intact seed coat and cells were noticed in the seeds dried to 5.0% moisture content and stored at lower temperatures (Fig 2).

CONCLUSION

The groundnut kernels can be stored well with 5.0% moisture content at controlled conditions for the period of 20 months. Therefore, because of the better viability, much reduced space required for storage, insignificant differences in regeneration interval and transportation convenience, conservation of decorticated seeds would be highly cost-effective under the controlled environmental conditions, as compared to pod storage.

Conflict of interest

The author declare that there is no conflict of interest.

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