D-5793
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RESEARCH ARTICLE Agricultural Science Digest

Storage Behaviour of Groundnut (*Arachis hypogaea* L.) Seeds under Different Storage Condition

M. Gayathri[1], R. Jerlin[1], T. Eevera[1], G. Amuthaselvi[2]

10.18805/ag.D-5793

ABSTRACT

Background: Seed deterioration is an unavoidable process during seed storage resulting in declined germination and vigour of the seeds and the seeds have different storage potential under different storage condition. Maintenance of germination and vigour requires new alternative method of storage conditions *viz.,* packaging material and temperature conditions. Storage potential of groundnut seeds cv. VRI 8 and the changes associated with the seeds stored under different storage conditions were investigated in this study.

Methods: The efficiency of modified atmospheric storage with different combination of CO_2, N_2 and O_2 and vacuum packaging under different storage temperature (25°C, 5°C and -5°C) for maintaining the storage behaviour of seeds up to 8 months were evaluated and the gas mixture was checked in gas analyzer at regular intervals.

Result: The seeds stored under modified atmospheric storage (MAS) condition with a gas mixture of 0% CO_2, 100% N_2 and 0% O_2 at -5°C temperature condition, maintained germination and seed vigour above 70% with a minimum increase in seed moisture content even after 8 months of storage and even when these seeds kept under ambient condition also maintained germination above 70% after 8 months of storage while the seeds stored under ambient condition registered less germination of below 70% by 6 months of storage itself. Down-regulation of antioxidant defence system *viz.,* catalase and peroxidase activity and the minimum accumulation of malondialdehyde and H_20_2 content in the embryo indicated the less oxidative damage in the seeds stored under MAS compared to ambient condition. Thus, the study highlighted that the seeds have better storage potential under modified atmospheric storage condition with low atmospheric temperature through maintaining the seed quality by reducing their metabolic activity and storing these seeds under ambient condition could be a cost-effective method.

Key words: Antioxidant enzymes, Groundnut, Lipid peroxidation, Low temperature, Modified atmospheric storage, Storage potential.

INTRODUCTION

Groundnut is a food legume crop belongs to Fabaceae family. It is an allotetraploid crop with a chromosome number of 2n=40. The seeds are rich source of proteins (22-30%) with high energy source (5.64 cal/g) and consist of 44-56% oil (Cobb and Johnson,1973).

Seed storage is a well-planned seed programme to maintain the quality of seeds with regard to germination and vigour.Behaviour of seeds under different storage conditions have major impact on seed quality maintenance (Silva *et al.,* 2018). Though the groundnut belongs to orthodox seeds which can tolerate low temperatures and can be dried to low moisture content, it has been reported to have short viability period (Mandizvo and Odindo, 2019).

The reason for shorter viability period might be due to deterioration caused by various mechanisms *viz.,* lipid auto-oxidation and lipid peroxidation, enzyme inactivation or protein degradation, cell membrane rupture and the loss of DNA integrity (Kumar *et al.,* 2015). The seeds stored with moisture of less than 6% undergoes lipid auto-oxidation while above 14% undergo lipid peroxidation and produces more of free radicals resulting the loss of membrane integrity.

Therefore, maintenance of these free radicals level either by enzymatic or non-enzymatic (antioxidants) activities along with high repair mechanisms in the embryo are required to maintain the seed viability during storage (Dona *et al.,* 2013). In seeds, the major ROS scavenging enzymes are catalase, peroxidase, ascorbate peroxidase and superoxide dismutase (Rajjou and Debeaujon, 2008).

Malondialdehyde and H_2O_2 content are considered as biomarker of oxidative damage to seeds (Bailly *et al.,* 1996) and their estimation in seeds helps to determine the lipid peroxidation and autoxidation (Cai *et al.,* 2011).

And during storage, loss of substantial desirable qualities of seeds will occur due to biotic and abiotic factors. To reduce these losses, prophylatic methods like mid storage

[1]Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[2]Department of Food Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

Corresponding Author: M. Gayathri, Department of Seed science and Technology, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India. Email: gayumani28@hotmail.com

How to cite this article: Gayathri, M., Jerlin, R., Eevera, T. and Amuthaselvi, G. (2023). Storage Behaviour of Groundnut (*Arachis hypogaea* L.) Seeds under Different Storage Condition. Agricultural Science Digest. doi:10.18805/ag.D-5793.

Submitted: 22-05-2023 **Accepted:** 24-06-2023 **Online:** 27-07-2023

corrections through various seed treatments are being followed. But application of these treatments has practical difficulties and so, the new alternative method for maintaining the quality and to extend the storage potential of the seeds is the need of an hour. At this juncture, a new method of vacuum packaging and gas packaging can be thought of.

Vacuum packaging is the form of hermetic storage, which involves storing the seeds in a film of low oxygen permeability then the removal of air from the package with hermetic sealing (Smith *et al*., 1990).

Modified atmosphere packaging (MAP) may be defined as 'the enclosure of seeds in a vapour and moisture impervious materials, in which the gaseous environment has been changed' (Young *et al.,* 1988) in order to maintain a higher quality during its natural life and to extend the shelf-life.

As groundnut seeds are rich source of nutrients with high oil content, the extended shelf life is impossible beyond 4 to 5 months from the date of harvesting. The present work has been carried out with the objective of assessing the various physiological and biochemical parameters under various storage conditionsin order to investigate the deterioration pattern in association with the antioxidant defence system in seeds.

MATERIALS AND METHODS

The experiments were carried out at the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore during 2021-2023. The groundnut seeds cv. VRI 8 were procured from Agricultural Research Station, Vridhachalam. The seeds were cleaned and dried to the moisture content of 6% and then 500 g of seeds were packed in 700-gauge polythene bags. The bags were kept at following storage conditions and stored for 8 months. The observations on physical, physiological, biochemical parameters for seeds as well as for oil were made at monthly intervals.

Treatment details	
T_1 -	Seeds stored in ambient condition
T_2 -	Seeds stored in vacuum packaging at 25°C
T_3 -	Seeds stored in vacuum packaging at 5°C
T_4 -	Seeds stored in vacuum packaging at -5°C
T_5 -	Seeds stored in MAS (60% CO_2, 40% N_2, 0% O_2) at 25°C
T_6 -	Seeds stored in MAS (60% CO_2, 40% N_2, 0% O_2) at 5°C
T_7 -	Seeds stored in MAS (60% CO_2, 40% N_2, 0% O_2) at -5°C
T_8 -	Seeds stored in MAS (40% CO_2, 60% N_2, 0% O_2) at 25°C
T_9 -	Seeds stored in MAS (40% CO_2, 60% N_2, 0% O_2) at 5°C
T_{10} -	Seeds stored in MAS (40% CO_2, 60% N_2, 0% O_2) at -5°C
T_{11} -	Seeds stored in MAS (0% CO_2, 100% N_2, 0% O_2) at 25°C
T_{12} -	Seeds stored in MAS (0% CO_2, 100% N_2, 0% O_2) at 5°C
T_{13} -	Seeds stored in MAS (0% CO_2, 100% N_2, 0% O_2) at -5°C

(MAS- Modified Atmospheric Storage).

The seed moisture content was calculated by Hot air oven method. The germination test was conducted in sand method as per procedures given by ISTA (2015). After the final count (10 days), number of normal seedlings were counted and expressed as germination percentage. The seed vigour was calculated as per Abdul-Baki and Anderson (1973).

The seeds were soaked in distilled water for 8 hours and then the electrical conductivity was estimated in the seed leachate using EC meter and was indicated in dSm^{-1} (Presley, 1958), while the dehydrogenase activity was observed as per procedure given by Kittock and Law (1968).

The groundnut oil was extracted from the seeds by applying the cold press technique. The cold pressed extraction of groundnut oil was effectuated using a twin-screw press method at temperatures below 60°C (Wang *et al.,* 2016). The oil content was determined by using the following formula:

$$\text{Oil content (\%)} = \frac{\text{Weight of oil extracted}}{\text{Weight of seed sample}} \times 100$$

Antioxidant enzymes activity was estimated by spectrophotometric method. The procedures were followed for catalase activity as per Aebi (1984) and peroxidase (Malik and Singh, 1980).

The estimated data were statistically analysed using completely randomized design (CRD) and the critical difference (CD) was computed at 5 per cent probability using AGRESS software. Wherever necessary, the per cent values were transformed to angular (Arc-sine) values before the analysis (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The results revealed that the germination percentage exhibited significant difference among treatments, period of storage and its interaction. Between the treatments, the highest germination percentage of 74% after 8 months of storage was recorded in the seeds stored in vacuum packaging and kept at -5°C(T_4) which was on par with modified atmospheric storage (0% CO_2, 100% N_2, 0% O_2) at -5°C (T_{13}) and (40% CO_2, 60% N_2, 0% O_2) at -5°C(T_{10}) while the lowest value (61%) was observed in seeds stored in ambient condition (T_1). Irrespective of the treatments, the germination percentage declined with increased period of storage (Table 1). The results were in accordance with Specht and Borner (1998) who observed a maintenance of germination in rye seeds when stored at high N_2 concentration than vacuum and high CO_2 condition. Groundnut seed kernels when exposed to modified atmospheric storage in gaseous combination of (60%) N_2 + (40%) CO_2 + (0%) O_2 in 700 gauge polyethylene bag had a higher germination and vigour upto ten months followed by vacuum storage (Vasudevan *et al.,* 2014).

The seeds stored under MAS (0% CO_2, 100% N_2, 0% O_2) and stored under -5°C maintain 74% germination after 8 months of storage. Similarly, MAS (0% CO_2, 100% N_2, 0% O_2) and kept under ambient condition, it could also maintain the germination above Indian Minimum Seed Certification Standards (IMSCS). Irrespective of the packaging, the seeds stored under -5°C recorded superiority over the other temperature conditions.

Similarly, the seed vigour exhibited higher vigour (308) in seeds stored in modified atmospheric storage (0% CO_2, 100% N_2, 0% O_2) at -5°C (T_{13}) while the lowest (231) was estimated in seeds stored in ambient condition (T_1) and it decreased with increasing storage period (Fig 1).

Similar results were observed for dehydrogenase activity also *i.e.*, seeds stored in modified atmospheric storage (0% CO_2, 100% N_2, 0% O_2) at 25°C (T_{11}) (2.819) and at (0% CO_2, 100% N_2, 0% O_2) at -5°C (T_{13}) (2.824) recorded higher activity depicting maintenance of seed viability even after 8 months of storage while the lowest (2.687) was observed in seeds stored in ambient condition (T_1) (Table 2). The viability loss in the seeds stored under low temperature condition (-5°C) in seeds stored under both vacuum packaging and MAS was recorded. The results were in accordance with Borem (2001) who concluded that the factors such as moisture, emergence, viability and insect after were kept at a check when stored at 5°C in bean seeds.

The electrical conductivity of seed leachate was high (0.336 dS/m) in seeds stored in ambient condition (T_1) indicating the increased seed deterioration while the low electrical conductivity was observed in (0% CO_2, 100% N_2, 0% O_2) at 5°C (T_{12}) (0.208 dS/m) and at (0% CO_2, 100% N_2, 0% O_2) at -5°C (T_{13}) (0.204 dS/m) (Table 3). The results were in accordance with the results estimated in onion, where the seeds stored under different combination of CO_2, N_2 and O_2 recorded less electrolyte leakage (Demirkaya *et al.,* 2010).

The viability and vigour loss is associated with declining cell membrane permeability. Even though the loss of viability and vigour is less in values in case of modified atmospheric storage, loss will depict the accumulation of harmful metabolic changes in the seeds (Delouche and Baskin, 1973). These changes are due to the production of ROS which attack on polyunsaturated fatty acids in the cell membrane resulting in the rupture of seed coat leading to the loss of cell membrane integrity. It can be determined by increasing electrical conductivity *i.e.*, more number of efflux of solute in the medium along with decreasing dehydrogenase activity in the living cells (Kumar *et al.,* 2015).

The seed moisture increased throughout the storage period irrespective of the packaging material and storage temperature. But, the percent increase in moisture content was less when the seeds were stored in modified atmospheric storage (0% CO_2, 100% N_2, 0% O_2) at -5°C (T_{13}) while the high percent of moisture was estimated in seeds stored in ambient condition (T_1) (Fig 2). Similar trend in moisture content was observed in onion seeds stored under modified atmospheric storage condition (Demirkaya *et al.,* 2010). The increasing trend of seed moisture irrespective of packaging might be due to moisture absorption by seeds by attaining equilibrium with environment during ageing process.

The percentage of oil extracted from the seeds was high in seeds stored in modified atmospheric storage (0% CO_2, 100% N_2, 0% O_2) at -5°C (T_{13}) with 48% even after 8 months of storage, while the lowest oil content was observed in seeds stored in ambient condition (T_1) which recorded 45.1% oil content. The total oil content decreased with increased

Table 1: Effect of different storage condition on germination (%) of groundnut seeds.

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
T_1	90 (71.56)	86 (68.02)	84 (66.42)	82 (64.89)	78 (62.02)	72 (58.05)	68 (55.55)	63 (52.53)	61 (51.35)
T_2	90 (71.56)	88 (69.73)	85 (67.21)	83 (65.64)	81 (64.15)	76 (60.66)	72 (58.05)	71 (57.41)	70 (56.78)
T_3	90 (71.56)	89 (70.63)	87 (68.86)	85 (67.21)	83 (65.64)	78 (62.02)	76 (60.66)	74 (59.34)	72 (58.05)
T_4	90 (71.56)	89 (70.63)	86 (68.02)	85 (67.21)	85 (67.21)	81 (64.15)	78 (62.02)	76 (60.66)	74 (59.34)
T_5	88 (69.73)	87 (68.86)	82 (64.89)	78 (62.02)	76 (60.66)	72 (58.05)	68 (55.55)	74 (59.34)	72 (58.05)
T_6	90 (71.56)	88 (69.73)	85 (67.21)	82 (64.89)	79 (62.72)	74 (59.34)	70 (56.78)	71 (57.41)	70 (56.78)
T_7	90 (71.56)	88 (69.73)	86 (68.02)	83 (65.64)	81 (64.15)	76 (60.66)	72 (58.05)	72 (58.05)	70 (56.78)
T_8	90 (71.56)	89 (70.63)	85 (67.21)	82 (64.89)	80 (63.43)	76 (60.66)	73 (58.69)	72 (58.05)	71 (57.41)
T_9	92 (73.57)	88 (69.73)	86 (68.02)	85 (67.21)	84 (66.42)	78 (62.02)	72 (58.05)	71 (57.41)	70 (56.78)
T_{10}	90 (71.56)	89 (70.63)	85 (67.21)	84 (66.42)	82 (64.89)	79 (62.72)	78 (62.02)	76 (60.66)	74 (59.34)
T_{11}	92 (73.57)	90 (71.56)	88 (69.73)	83 (65.64)	84 (66.42)	80 (63.43)	74 (59.34)	73 (58.69)	72 (58.05)
T_{12}	90 (71.56)	89 (70.63)	87 (68.86)	86 (68.02)	84 (66.42)	80 (63.43)	76 (60.66)	74 (59.34)	73 (58.69)
T_{13}	92 (73.57)	90 (71.26)	88 (69.73)	86 s (68.02)	85 (67.21)	81 (64.15)	78 (62.02)	75 (60.00)	74 (59.34)
Mean	90 (71.56)	88 (69.73)	86 (68.02)	83 (65.64)	82 (64.89)	77 (61.34)	73 (64.89)	72 (58.05)	71 (57.41)

	T	P	T×P
SEd	0.4159	0.3461	1.2478
CD(P=0.05)	0.8237	0.6854	2.4712

(Figures in paranthesis are arc-sine transformed vales).

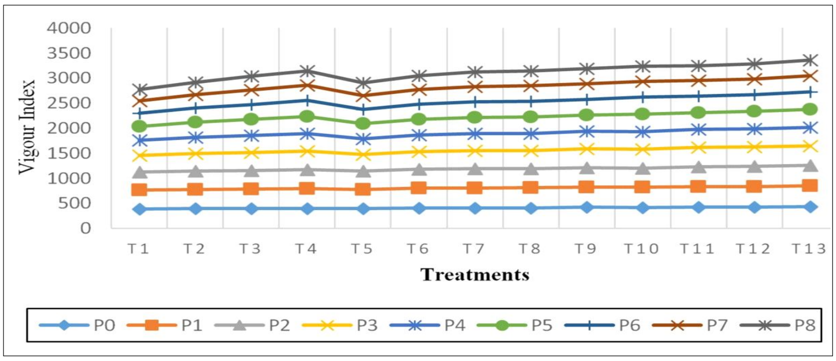

Fig 1: Effect of different storage condition on vigour index.

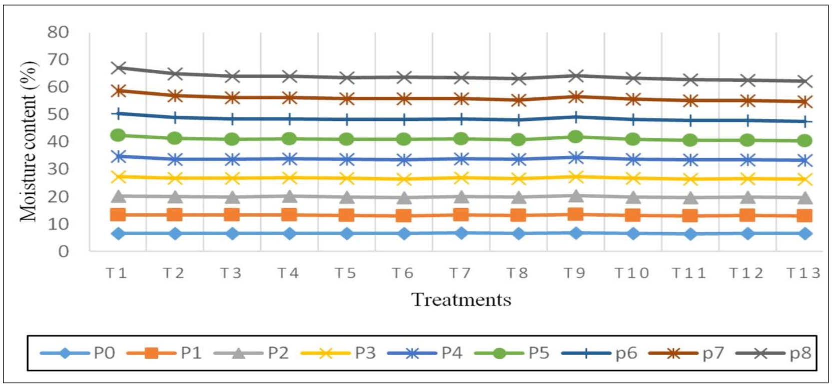

Fig 2: Effect of different storage condition on seed moisture content (%).

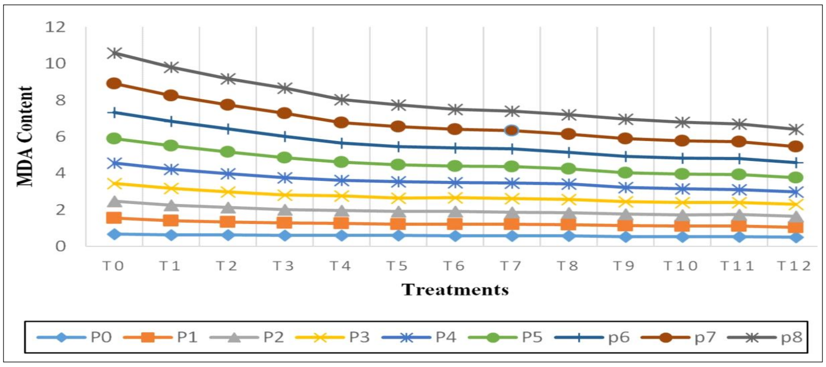

Fig 3: Effect of different storage condition on MDA content (μM/g of FW).

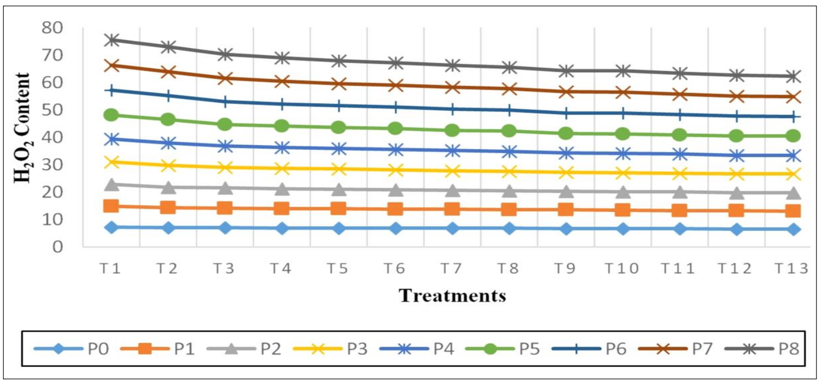

Fig 4: Effect of different storage condition on H_2O_2 content (μM/g of FW).

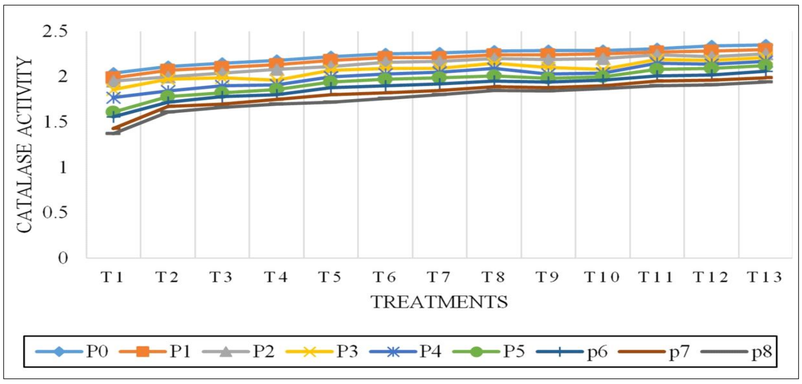

Fig 5: Effect of different storage condition on catalase activities (μM H_2O_2 reduced min^{-1} mg^{-1} protein).

Table 2: Effect of different storage condition on dehydrogenase activity (OD value) of groundnut seeds.

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
T_1	2.812	2.793	2.785	2.766	2.742	2.728	2.717	2.699	2.687
T_2	2.823	2.811	2.802	2.792	2.786	2.777	2.765	2.756	2.742
T_3	2.832	2.828	2.816	2.807	2.792	2.784	2.773	2.766	2.757
T_4	2.845	2.848	2.837	2.825	2.813	2.804	2.798	2.786	2.774
T_5	2.854	2.849	2.841	2.837	2.822	2.817	2.800	2.792	2.781
T_6	2.863	2.860	2.855	2.841	2.834	2.821	2.813	2.800	2.793
T_7	2.864	2.860	2.858	2.849	2.840	2.833	2.827	2.811	2.800
T_8	2.867	2.863	2.859	2.851	2.844	2.839	2.831	2.820	2.810
T_9	2.869	2.859	2.854	2.851	2.848	2.840	2.839	2.826	2.811
T_{10}	2.869	2.863	2.859	2.853	2.849	2.841	2.840	2.823	2.814
T_{11}	2.870	2.867	2.862	2.858	2.851	2.847	2.844	2.831	2.819
T_{12}	2.868	2.865	2.861	2.856	2.847	2.841	2.839	2.824	2.818
T_{13}	2.870	2.867	2.864	2.860	2.857	2.853	2.847	2.833	2.824
Mean	2.854	2.849	2.843	2.834	2.825	2.817	2.810	2.797	2.787
	T		P				T×P		
SEd	0.0163		0.0135				0.0488		
CD (P=0.05)	0.0322		0.0268				0.0967		

Table 3: Effect of different storage condition on electrical conductivity (dS/m) of groundnut seeds.

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
T_1	0.167	0.189	0.197	0.216	0.245	0.279	0.292	0.311	0.336
T_2	0.163	0.179	0.184	0.197	0.200	0.211	0.243	0.266	0.285
T_3	0.162	0.177	0.181	0.195	0.199	0.209	0.235	0.245	0.266
T_4	0.159	0.165	0.173	0.188	0.181	0.193	0.212	0.232	0.254
T_5	0.160	0.169	0.171	0.182	0.190	0.197	0.227	0.241	0.265
T_6	0.157	0.168	0.176	0.179	0.183	0.191	0.207	0.221	0.245
T_7	0.153	0.161	0.172	0.179	0.181	0.188	0.200	0.214	0.240
T_8	0.149	0.157	0.166	0.174	0.180	0.183	0.199	0.210	0.236
T_9	0.145	0.149	0.154	0.165	0.172	0.178	0.192	0.211	0.228
T_{10}	0.143	0.154	0.160	0.168	0.173	0.176	0.185	0.201	0.222
T_{11}	0.139	0.144	0.159	0.163	0.170	0.176	0.182	0.200	0.219
T_{12}	0.138	0.147	0.153	0.160	0.164	0.169	0.176	0.197	0.208
T_{13}	0.134	0.140	0.146	0.158	0.166	0.168	0.174	0.192	0.204
Mean	0.151	0.161	0.169	0.179	0.185	0.194	0.210	0.226	0.247
	T		P				T×P		
SEd	0.0014		0.0012				0.0042		
CD (P=0.05)	0.0028		0.0023				0.0084		

storage period (Table 4). Reduction in oil content in seeds are due to the seed deterioration caused by the ROS attack in the lipid membranes.

Quantification of MDA and H_2O_2 content in the embryo exhibited an increasing trend in accumulation of MDA and H_2O_2 content with increasing storage period. But the percent increase was less in T_{13} (64% for MDA and 10% for H_2O_2 content) while high percent increase was observed in T_1 (82% for MDA and 26% for H_2O_2 content) (Fig 3 and 4). Accumulation of MDA and H_2O_2 content during ageing are reported in wheat (Lehner *et al.,* 2008), cotton (Goel *et al.,* 2003) and soybean (Sharma *et al.,* 2013). McDonald (1999) suggested that decrease in the initiation of free radicals, extending the longevity of the seeds with a reduction in the levels of lipid peroxidation and production of damaging compounds could be caused by O_2 elimination for storage atmosphere of seed.

Lipid peroxidation and auto-oxidation were highly dependent on seed moisture content. If the seeds have moisture less than 6%, lipid auto-oxidation will occur and produce ROS, whereas oxidative enzymes will be responsible for ROS production (lipid peroxidation) when the moisture is more than 14% (McDonald, 1999). As the seed moisture reached 7% under MAS and 8% under ambient condition which are above 6%, the reduction in oil content and accumulation of MDA and H_2O_2 content (final products of lipid peroxidation) in the embryo is due to lipid peroxidation leading to seed deterioration with reduced viability and vigour (El-Maarouf-Bouteau *et al.,* 2011).

The seeds stored under modified atmospheric storage registered a less increase in MDA and H_2O_2 content as it had lesser increase in seed moisture content and had a less metabolic changes compared to seeds stored under ambient condition. And also the storage temperature had a greater influence on storage behaviour of seeds. The seeds packed by modified atmospheric storage with 100% N_2 and eliminating O_2, CO_2 stored under -5°C showed a lesser increase in moisture content with less accumulation of MDA and H_2O_2 content in the embryo even after 8 months of storage.

Similarly, declining trend was observed in antioxidant enzymes like catalase and peroxidase activity. But the percent decrease was less in T_{13} (15% for peroxidase and 4% for catalase activity) while the high per cent increase was observed in T_1 (59% for peroxidase and 21% for catalase activity) (Fig 5 and 6). Begum *et al.* (2014) stated that reduction in catalase and peroxidase activity was highly evident in case of groundnut where the reduction in peroxidase enzyme activity was from 0.236 to 0.444 OD 10 min^{-1} during higher storage periods. The reduced antioxidant defense system was associated with inability of the seeds to repair the damage caused by ageing and seed deterioration (Mittler, 2002; Mullan and McDowell, 2011).

The metabolic activity *i.e.*, lipid peroxidation and antioxidant activity in seeds stored under MAS (100% N_2 and eliminating O_2, CO_2) was less than seeds stored under MAS (60% CO_2, 40% N_2, 0% O_2) and (40% CO_2, 60% N_2, 0% O_2) which might be due to the less influence of carbon-

Table 4: Effect of different storage condition on oil content (%) of groundnut seeds.

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
T_1	47.9 (43.79)	47.4 (43.50)	47.1 (43.33)	46.8 (43.16)	46.6 (43.05)	46.2 (42.82)	45.9 (42.64)	45.4 (42.36)	45.1 (42.18)
T_2	48.1 (43.91)	47.9 (43.79)	47.6 (43.62)	47.3 (43.45)	47.0 (43.28)	46.8 (43.16)	46.4 (42.93)	46.1 (42.76)	45.9 (42.64)
T_3	48.2 (43.96)	48.1 (43.91)	47.9 (43.79)	47.6 (43.62)	47.1 (43.33)	46.9 (43.22)	46.5 (42.99)	46.3 (42.87)	46.1 (42.76)
T_4	48.2 (43.96)	48.2 (43.96)	48.1 (43.91)	47.8 (43.73)	47.3 (43.45)	47.0 (43.28)	46.8 (43.16)	46.6 (43.05)	46.4 (42.93)
T_5	48.4 (44.08)	48.3 (44.02)	48.1 (43.91)	47.7 (43.68)	47.4 (43.50)	47.0 (43.28)	46.9 (43.22)	46.5 (42.99)	46.4 (42.93)
T_6	48.6 (44.19)	48.4 (44.08)	48.2 (43.96)	48.0 (43.85)	47.8 (43.73)	47.4 (43.50)	47.1 (43.33)	46.9 (43.22)	46.6 (43.05)
T_7	48.7 (44.25)	48.5 (44.14)	48.2 (44.96)	47.8 (43.73)	47.6 (43.62)	47.5 (43.56)	47.2 (43.39)	47 (43.28)	46.9 (43.22)
T_8	48.9 (44.36)	48.6 (44.19)	48.5 (44.14)	48.2 (43.96)	48.0 (43.85)	47.8 (43.73)	47.5 (43.56)	47.2 (43.39)	47 (43.28)
T_9	49.2 (44.54)	48.8 (44.31)	48.6 (44.19)	48.3 (44.02)	48.1 (43.91)	47.9 (43.79)	47.6 (43.62)	47.3 (43.45)	47.1 (43.33)
T_{10}	49.3 (44.59)	49.0 (44.42)	48.9 (44.36)	48.6 (44.19)	48.2 (43.96)	48.0 (43.85)	47.8 (43.73)	47.5 (43.56)	47.6 (43.62)
T_{11}	49.4 (44.65)	49.2 (44.54)	49.0 (44.42)	48.8 (44.31)	48.6 (44.19)	48.3 (44.02)	48.0 (43.85)	47.8 (43.73)	47.6 (43.62)
T_{12}	49.4 (44.65)	49.4 (44.65)	49.1 (44.48)	48.9 (44.36)	48.7 (44.25)	48.4 (44.08)	48.2 (43.96)	47.9 (43.79)	47.7 (43.68)
T_{13}	49.6 (44.77)	49.5 (44.71)	49.2 (44.54)	49.0 (44.42)	48.9 (44.36)	48.7 (44.25)	48.5 (44.14)	48.2 (43.98)	48 (43.85)
Mean	48.7 (44.25)	48.5 (44.14)	48.3 (44.02)	48.0 (43.85)	47.7 (43.68)	47.5 (43.56)	48.5 (44.14)	47.0 (43.28)	46.8 (43.17)

	T	P	T×P
SEd	0.1158	0.0963	0.3473
CD(P=0.05)	0.2293	0.1908	0.6878

(Figures in paranthesis are arc-sine transformed vales).

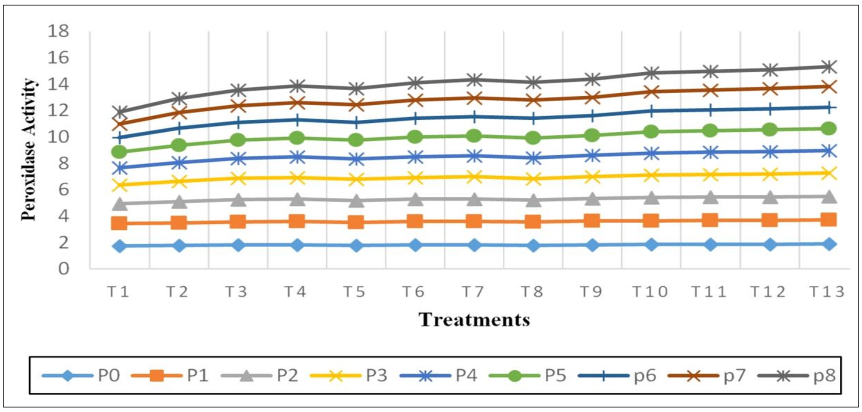

Fig 6: Effect of different storage condition on peroxidase activities (U mg^{-1} protein min^{-1}).

dioxide and oxygen in seed respiration and the inert activity of nitrogen over the seeds which has no influence on seed metabolic activity (Specht and Borner, 1998; Manolopoulou and Varzakas, 2016).

CONCLUSION

Groundnut seeds with high initial quality stored under different storage condition exhibited different storage behaviour. The seeds packed in modified atmospheric packaging and stored under low temperatures *viz.,* -5°C and 5°C had a better shelf life with reduced biochemical and physiological changes which was followed by vacuum packaging compared to seeds stored under ambient condition. Especially, when the seeds are stored under MAS with combination of 0% CO_2, 100% N_2, 0% O_2 gases at -5°C registered a maintenance of germination, vigour and less harmful alterations in embryo showing a high evident that modified atmospheric storage along with low storage temperature, a better alternative method for storing seeds and can provide a better storage environment. Though the seed germination and vigour were superior in MAS (0% CO_2, 100% N_2, 0% O_2) at -5°C temperature condition, the seeds stored under MAS (0% CO_2, 100% N_2, 0% O_2) under ambient condition also maintained germination and vigour above IMSCS. Considering the cost of storing seeds under low temperature of -5°C, storing the seeds in MAS with combination of 0% CO_2, 100% N_2, 0% O_2 gases under ambient condition would be the better alternative method for storing the groundnut seeds.

Conflict of interest: None.

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