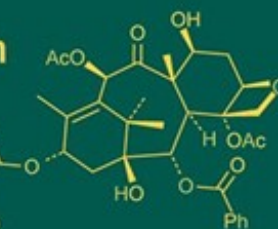
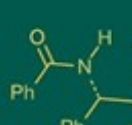
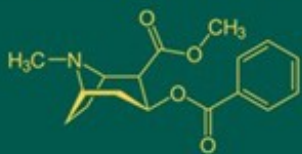


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Influence of packaging materials on seed quality and biochemical attributes of onion (*Allium Cepa* L.) seeds during storage

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ABSTRACT

A laboratory investigation was conducted at the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad, during 2025-26, to study the influence of packaging material on seed quality attributes and biochemical changes of onion (cv. *Bhima Super*) seeds during ambient storage. Onion seeds were packed in four packaging materials, viz., aluminium pouch (P_1), 700-gauge polythene bag (P_2), vacuum packaging (P_3) and cloth bag (P_4 : control) and stored under ambient conditions for ten months, with seed quality assessed at monthly intervals and biochemical parameters assessed at the initial, mid (5th month) and final (10th month) storage stages. The experiment was laid out in a Factorial Completely Randomised Design with two factors and five replications. Irrespective of packaging material, speed of germination declined from 47.69 to 32.14, seedling dry weight from 22.90 to 18.16 mg/10 seedlings, and Seedling Vigour Index-II from 2110 to 1426 between the first and tenth month of storage, while seed moisture content increased from 5.90 to 8.36 per cent over the same period. Total dehydrogenase and peroxidase activities declined from 0.53 to 0.20 OD and 1.87 to 1.29 $\mu\text{mol/cm/min/g}$, respectively, between the initial and final storage stages. Among the packaging materials, aluminium pouch recorded the highest mean speed of germination (46.75), dry weight (22.51 mg/10 seedlings), SVI-II (2092), dehydrogenase activity (0.40 OD) and peroxidase activity (1.72 $\mu\text{mol/cm/min/g}$), and the lowest mean moisture content (5.73%), on par with vacuum packaging, whereas cloth bag recorded the poorest performance across all traits. The interaction between storage period and packaging material was significant for all the traits studied. At the end of the storage period, seeds stored in aluminium pouch (S_{10P1}) retained the highest speed of germination (43.98), dry weight (21.04 mg/10 seedlings), SVI-II (1876) and enzyme activities, and the lowest moisture content (5.81%), whereas seeds stored in cloth bag (S_{10P4}) recorded the poorest values for all traits. Thus, aluminium pouch and vacuum packaging effectively minimised physiological and biochemical deterioration and are recommended for maintaining the quality of onion seeds during prolonged ambient storage.

Keywords: Biochemical change, Onion seed, Packaging materials, Seed storage, Seed quality

Introduction

Onion (*Allium cepa* L.), a member of the family Amaryllidaceae, is one of the most important commercial spice-vegetable crops grown worldwide. During 2024-25, onion was cultivated globally on 5.84 m ha with a production of 111.2 million tonnes; India ranked first in area (17.74 lakh ha) and second in production (28.87 million tonnes) after China, with an average productivity of 16.28 MT/ha, while Karnataka contributed 2.2 million tonnes from 1.73 lakh ha (Anon., 2024) [1].

Seed is the basic input in agriculture, and successful crop production depends largely on the quality of seed used for sowing. Onion is considered a poor storer, since it is a living entity that loses viability within a year under ambient storage conditions, and its higher initial seed moisture content and delicate seed coat render it particularly susceptible to deterioration (Kamaei *et al.*, 2024) [2]. Seed deterioration during storage arises from reactive oxygen species generated through respiration, which trigger lipid peroxidation of membrane phospholipids, inactivate respiratory and antioxidant enzymes, and progressively erode germinability and vigour (Brar *et al.*, 2019) [3].

The packaging material used for storage strongly influences the rate of this deterioration by regulating the exchange of moisture and gases between the seed and its surrounding environment. Containers that restrict moisture entry and limit oxygen movement have been reported to preserve seed viability for longer periods under ambient conditions, whereas porous packaging exposes seed to continuous moisture fluctuation that accelerates physiological ageing (Singh *et al.*, 1992) [4]. Selecting a suitable packaging material is therefore essential for maintaining the vigour and biochemical integrity of onion seed held in storage.

Although the influence of storage duration and packaging material on seed quality has been studied individually in onion and related vegetable crops, integrated evaluations tracking both physiological (germination, vigour, moisture) and biochemical (enzymatic) markers of deterioration together over an extended ten-month ambient storage period remain limited. Against this backdrop, the present investigation was undertaken to assess the influence of packaging material on the physiological and biochemical changes of onion (cv. *Bhima Super*) seeds during storage.

Material and Methods

The experiment was conducted at the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad, during 2025-26. Freshly harvested onion seeds of cv. *Bhima Super*, obtained from the Seed Unit, University of Agricultural Sciences, Dharwad, served as the test material.

The experiment was laid out in a Factorial Completely Randomised Design with two factors and five replications: Factor 1 being packaging material (P₁: aluminium pouch; P₂: 700-gauge polythene bag; P₃: vacuum packaging; P₄: cloth bag/control) and Factor 2 being storage period (S₁ to S₁₀: first to tenth month after storage). Ten grams of seed were packed in each packaging material and stored under ambient conditions for ten months (July 2025 - April 2026), with samples drawn monthly for physiological evaluation.

Speed of germination was recorded on paper medium using four replications of 100 seeds each, based on daily germination counts up to the final count (12 days), and calculated following the formula of Maguire (1962) [5]. Ten normal seedlings were randomly selected from the germination test and oven-dried at 80 ± 2 °C for 24 h to record seedling dry weight (mg/10 seedlings). Seedling Vigour Index-II was computed as germination (%) × mean seedling dry weight, following Abdul-Baki and Anderson (1973) [6]. Seed moisture content (%) was determined on a wet-weight basis by the hot-air oven method (103 ± 2 °C for 17 ± 1 h) as per ISTA procedure (Anon., 2021) [7].

Total dehydrogenase activity was assessed by the tetrazolium (TTC) staining method, with absorbance recorded at 470 nm using a UV-Vis spectrophotometer (Kittoch *et al.*, 1968) [8]. Peroxidase activity was assayed following Castillo *et al.* (1994) [9], based on the oxidation of guaiacol to tetraguaiacol measured at 470 nm and expressed as μmol/cm²/min/g seed fresh weight. Biochemical parameters were analysed at the initial (S₀), mid (5th month, S₅) and final (10th month, S₁₀) storage stages. Data were analysed statistically for FCRD, with critical difference computed at the 1 per cent level of significance (Gomez *et al.*, 2010) [10].

Results and Discussion

Speed of germination declined progressively with advancing storage period (Table 1). Irrespective of packaging material, the mean speed of germination declined from 47.69 at one month (S₁) to 32.14 after ten months (S₁₀) of storage, a decline that reflects the natural process of seed ageing: continued low-rate respiration under ambient storage generates reactive oxygen species that progressively oxidise membrane phospholipids and inactivate the enzymes governing mobilisation of reserves to the embryonic axis, thereby slowing radicle emergence irrespective of the packaging environment (Barua *et al.*, 2009 [11]; Khan *et al.*, 2004) [11, 12]. Among packaging materials, aluminium pouch (P₁) recorded the highest mean speed of germination (46.75), followed closely by vacuum packaging (P₃: 46.43), while 700-gauge polythene bag (P₂: 39.25) was intermediate and cloth bag (P₄) recorded the lowest (31.97). The interaction between storage period and packaging material was significant; the highest speed of germination (43.98) was recorded in seeds stored in aluminium pouch (S₁₀P₁), while the lowest (13.34) was recorded in cloth bag at the end of storage (S₁₀P₄). The superior performance of aluminium pouch and vacuum packaging is attributable to their excellent moisture- and gas-barrier properties, which restricted respiration, lipid peroxidation and depletion of reserves essential for radicle protrusion, whereas the porous cloth bag allowed continuous moisture and oxygen exchange

that hastened enzymatic degradation. These findings are in agreement with Rao *et al.* (2006) [13] and Tripathi and Lawande (2014) [14] in onion, and Hunje *et al.* (2007) [15] in chilli, who reported superior retention of viability and vigour in aluminium- and polythene-based packaging over cloth bag.

Seedling dry weight also declined progressively with advancing storage period (Table 2). Irrespective of packaging material, mean dry weight decreased from 22.90 mg/10 seedlings at one month (S₁) to 18.16 mg/10 seedlings after ten months (S₁₀), reflecting cumulative ageing-related impairment of the seed's mitochondrial respiratory apparatus, which increasingly leaks electrons that generate reactive oxygen species and degrade the enzymes required for efficient mobilisation of reserves once germination begins (Bhuker *et al.*, 2022 [16]; Rai and Mishra, 2017) [16, 17]. Among packaging materials, aluminium pouch (P₁) recorded the highest mean dry weight (22.51 mg/10 seedlings), followed by vacuum packaging (P₃: 21.80 mg/10 seedlings) and 700-gauge polythene bag (P₂: 21.14 mg/10 seedlings), while cloth bag (P₄) recorded the lowest (18.71 mg/10 seedlings). The interaction was significant; after ten months of storage, the highest dry weight (21.04 mg/10 seedlings) was recorded in aluminium pouch (S₁₀P₁), while the lowest (13.12 mg/10 seedlings) was recorded in cloth bag (S₁₀P₄). The higher dry-matter retention under aluminium pouch and vacuum packaging is attributed to restricted respiratory loss of stored reserves under moisture- and oxygen-impervious conditions, consistent with Mollah *et al.* (2016) [18] and Lokesh *et al.* (2020) [19], who reported better retention of seed quality in moisture-impervious containers than in porous ones.

Being a composite trait derived from germination and dry weight, Seedling Vigour Index-II (SVI-II) declined progressively with advancing storage, following the same overall pattern (Table 3). The mean SVI-II declined from 2110 at one month (S₁) to 1426 after ten months (S₁₀), a decline that reflects the integrated effect of the simultaneous, time-dependent deterioration in germination and dry-matter accumulation, since vigour indices are products rather than sums of their components (Bhuker *et al.*, 2022 [16]; Hossain *et al.*, 2025) [16, 20]. Among packaging materials, the highest mean SVI-II was recorded in aluminium pouch (P₁: 2092), followed by vacuum packaging (P₃: 1990) and 700-gauge polythene bag (P₂: 1862), while cloth bag (P₄) recorded the lowest (1224). The interaction was significant; the highest SVI-II (1876) was recorded in aluminium pouch during the first month (S₁₀P₁), while the lowest (616) was recorded in cloth bag after ten months of storage (S₁₀P₄). These results corroborate Fedá *et al.* (2018) [21] and Pachabhai and Pai (2018) [22], who reported superior vigour retention in aluminium- and polythene-packed onion seed compared with cloth bag.

Seed moisture content increased significantly and progressively with advancing storage period (Table 4), from 5.90 per cent at one month (S₁) to 8.36 per cent after ten months (S₁₀), irrespective of packaging material. This increase reflects the hygroscopic nature of seed, which continuously exchanges moisture with the surrounding atmosphere until equilibrium with ambient relative humidity is attained, with prolonged exposure accelerating membrane phospholipid peroxidation (Goel and Sheoran, 2003 [23]; Parihar *et al.*, 2014) [23, 24]. Among packaging materials, aluminium pouch (P₁) maintained the lowest mean moisture content (5.73%), on par with vacuum packaging (P₃: 5.74%), while cloth bag (P₄) recorded the highest (9.54%). The interaction was significant; the lowest moisture content (5.81%) was recorded in aluminium pouch (S₁₀P₁), while the highest (13.78%) was recorded in cloth bag at the end of storage (S₁₀P₄). The hermetic, moisture-impervious properties of aluminium pouch and vacuum packaging effectively prevented ingress of atmospheric moisture, whereas the highly permeable cloth bag facilitated continuous moisture absorption, in agreement with Mersal *et al.* (2018) [25] and Jakhar *et al.* (2021) [26], in onion.

Both total dehydrogenase (TDH) and peroxidase (POD) activities declined steadily with advancing storage, with a significant storage period × packaging material interaction confirming a faster decline in the poorly protective cloth bag (Fig. 1 and Fig. 2). Dehydrogenase ac

tivity, uniform at 0.53 OD across all packaging materials at the initial stage (S_0), declined to a mean of 0.35 OD at mid-storage (S_5) and further to 0.20 OD by the end of storage (S_{10}). At the final stage, aluminium pouch ($S_{10}P_1$: 0.28 OD) and vacuum packaging ($S_{10}P_3$: 0.27 OD) retained the highest activity, followed by 700-gauge polythene bag ($S_{10}P_2$: 0.19 OD), while cloth bag ($S_{10}P_4$: 0.08 OD) recorded the lowest. Among packaging materials, mean dehydrogenase activity was highest in aluminium pouch (P_1 : 0.40 OD), on par with vacuum packaging (P_3 : 0.40 OD), and lowest in cloth bag (P_4 : 0.29 OD). Dehydrogenase activity reflects the respiratory vigour of living seed tissue, and its higher retention under low-permeability packaging indicates slower deterioration of mitochondrial membranes and their associated enzyme complexes, in agreement with Bhanuprakash *et al.* (2006) [27] and Brar *et al.* (2019) [3] in onion.

Peroxidase activity showed a comparable, even sharper decline, from a uniform initial value of 1.87 $\mu\text{mol/cm/min/g}$ (S_0) to a mean of 1.57 $\mu\text{mol/cm/min/g}$ at mid-storage (S_5) and 1.29 $\mu\text{mol/cm/min/g}$ by the end of storage (S_{10}). At the final stage, the highest activity was recorded in aluminium pouch ($S_{10}P_1$: 1.58 $\mu\text{mol/cm/min/g}$), on par with vacuum packaging ($S_{10}P_3$: 1.57 $\mu\text{mol/cm/min/g}$), followed by 700-gauge polythene bag ($S_{10}P_2$: 1.13 $\mu\text{mol/cm/min/g}$), while cloth bag ($S_{10}P_4$: 0.86 $\mu\text{mol/cm/min/g}$) recorded the lowest. Among packaging materials, mean peroxidase activity was highest in aluminium pouch (P_1 : 1.72 $\mu\text{mol/cm/min/g}$), on par with vacuum packaging (P_3 : 1.71 $\mu\text{mol/cm/min/g}$), and lowest in cloth bag (P_4 : 1.34 $\mu\text{mol/cm/min/g}$). Peroxidase is a key component of the enzymatic antioxidant defence system that detoxifies hydrogen peroxide

generated during respiration and storage stress; its better retention under low-permeability packaging points to a more functional antioxidant system that limits oxidative damage from reactive oxygen species, consistent with Demirkaya *et al.* (2010) [28] and Chauhan *et al.* (2011) [29], who reported progressive declines in these enzyme activities with advancing seed age.

Conclusion

Seed quality attributes of onion (cv. *Bhima Super*) declined progressively with advancing storage period under ambient conditions, but the rate of physiological and biochemical deterioration was strongly influenced by the packaging material used. Aluminium pouch and vacuum packaging were the most effective in preserving speed of germination, seedling dry weight, seedling vigour, and dehydrogenase and peroxidase activities, and in restricting moisture uptake, whereas 700-gauge polythene bag performed moderately and cloth bag recorded the fastest decline. Moisture and oxygen-impervious packaging is therefore recommended for maintaining the quality of onion seed intended for extended ambient storage.

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Table 1. Effect of packaging materials on speed of germination of onion (cv. *Bhima Super*) during storage

Storage period	Packaging material				Mean
	P ₁	P ₂	P ₃	P ₄	
S ₁ (1 MAS)	47.94	47.8	47.88	47.14	47.69
S ₂ (2 MAS)	47.9	47.16	47.8	46.46	47.33
S ₃ (3 MAS)	47.88	46.06	47.78	43.54	46.31
S ₄ (4 MAS)	47.84	43.56	47.62	38.9	44.48
S ₅ (5 MAS)	47.76	40.96	47.56	35.02	42.82
S ₆ (6 MAS)	47.68	38.32	47.48	30.78	41.06
S ₇ (7 MAS)	46.4	36.26	46.54	26.62	38.95
S ₈ (8 MAS)	45.7	33.54	44.92	20.66	36.2
S ₉ (9 MAS)	44.42	30.54	43.84	17.2	34
S ₁₀ (10 MAS)	43.98	28.36	42.88	13.34	32.14
Mean	46.75	39.25	46.43	31.97	41.1
	S	P	S × P		
S.E.m±	0.08	0.05	0.16		
CD @1%	0.3	0.19	0.6		

Table 2. Effect of packaging materials on seedling dry weight (mg/10 seedlings) of onion (cv. *Bhima Super*) during storage

Storage period	Packaging material				Mean
	P ₁	P ₂	P ₃	P ₄	
S ₁ (1 MAS)	23.58	22.46	23.06	22.5	22.9
S ₂ (2 MAS)	23.5	22.42	22.9	22.48	22.82
S ₃ (3 MAS)	23.26	22.32	22.7	22.4	22.67
S ₄ (4 MAS)	23.24	22.24	22.68	21.34	22.37
S ₅ (5 MAS)	22.92	21.88	22.58	21.14	22.13
S ₆ (6 MAS)	22.86	21.24	22.46	18.78	21.33
S ₇ (7 MAS)	22.3	21.1	21.2	16.82	20.35
S ₈ (8 MAS)	21.24	20	20.84	14.42	19.12
S ₉ (9 MAS)	21.18	19.08	19.86	14.1	18.55
S ₁₀ (10 MAS)	21.04	18.74	19.76	13.12	18.16
Mean	22.51	21.14	21.8	18.71	21.04

(continued on next page)

Storage period	Packaging material			Mean
	S	P	S × P	
S.Em±	0.11	0.07	0.23	
CD @1%	0.41	0.26	0.83	

Table 3. Effect of packaging materials on Seedling Vigour Index-II of onion (cv. *Bhima Super*) during storage

Storage period	Packaging material				Mean
	P ₁	P ₂	P ₃	P ₄	
S ₁ (1 MAS)	2235	2079	2172	1955	2110
S ₂ (2 MAS)	2218	2067	2134	1667	2021
S ₃ (3 MAS)	2181	2048	2111	1539	1970
S ₄ (4 MAS)	2170	2037	2105	1438	1937
S ₅ (5 MAS)	2140	1999	2082	1357	1894
S ₆ (6 MAS)	2130	1932	2061	1194	1829
S ₇ (7 MAS)	2073	1776	1916	945	1677
S ₈ (8 MAS)	1958	1647	1842	787	1558
S ₉ (9 MAS)	1939	1545	1751	747	1495
S ₁₀ (10 MAS)	1876	1487	1727	616	1426
Mean	2092	1862	1990	1224	1792
	S	P	S × P		
S.Em±	9.58	6.06	19.16		
CD @1%	35.31	22.33	70.63		

Figure 2. Influence of storage period and packaging material on per-oxidase activity of onion seeds**Table 4.** Effect of packaging materials on seed moisture content (%) of onion (cv. *Bhima Super*) during storage

Storage period	Packaging material				Mean
	P ₁	P ₂	P ₃	P ₄	
S ₁ (1 MAS)	5.7	5.7	5.7	6.5	5.9
S ₂ (2 MAS)	5.7	5.72	5.71	6.95	6.02
S ₃ (3 MAS)	5.7	5.75	5.71	7.47	6.16
S ₄ (4 MAS)	5.71	5.79	5.71	8.19	6.35
S ₅ (5 MAS)	5.72	5.82	5.73	8.84	6.53
S ₆ (6 MAS)	5.72	6.05	5.73	9.25	6.69
S ₇ (7 MAS)	5.74	6.58	5.74	9.93	6.99
S ₈ (8 MAS)	5.75	7.01	5.77	11.83	7.59
S ₉ (9 MAS)	5.79	7.63	5.8	12.63	7.96
S ₁₀ (10 MAS)	5.81	8.05	5.82	13.78	8.36
Mean	5.73	6.41	5.74	9.54	6.86
	S	P	S × P		
S.Em±	0.01	0.01	0.02		
CD @1%	0.03	0.02	0.06		

Figures

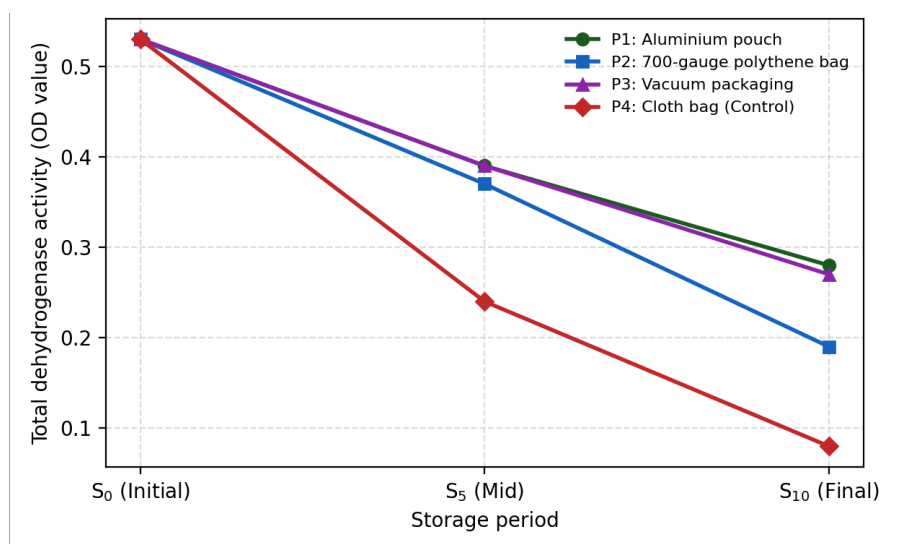


Table 4. Effect of packaging materials on seed moisture content (%) of onion (cv. *Bhima Super*) during storage

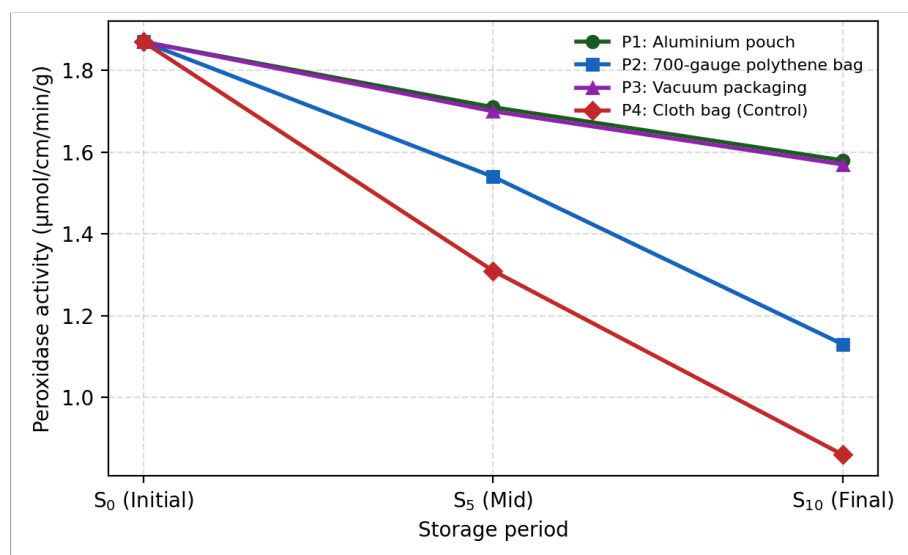


Figure 1. Influence of storage period and packaging material on total dehydrogenase activity of onion seeds

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30. P1-Aluminium pouch; P2-700-gauge polythene bag; P3-Vacuum packaging; P4-Cloth bag (control); S1-S10-first to tenth month after storage (MAS).
31. P1-Aluminium pouch; P2-700-gauge polythene bag; P3-Vacuum packaging; P4-Cloth bag (control); S1-S10-first to tenth month after storage (MAS).
32. P1-Aluminium pouch; P2-700-gauge polythene bag; P3-Vacuum packaging; P4-Cloth bag (control); S1-S10-first to tenth month after storage (MAS).
33. P1-Aluminium pouch; P2-700-gauge polythene bag; P3-Vacuum packaging; P4-Cloth bag (control); S1-S10-first to tenth month after storage (MAS).

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