International Journal of Research Studies in Biosciences (IJRSB)
Volume 2, Issue 2, March 2014, PP 25-36
www.arcjournals.org

Studies on Effect of Modified Atmospheric Storage Condition on Storability of Groundnut (*Arachis Hypogaea* L.) Seed Kernels

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Abstract: *In modified atmospheric storage assays on seed quality of Groundnut seed kernels revealed that the seed kernels exposed to gaseous combination of 60 %* N_2 *+ 40 %* CO_2 *+ 0 %* O_2 *and stored in 700 gauge polyethylene bag maintained better quality in terms of germination and vigour up to ten months of storage followed by vacuum storage, whereas in control, prescribed germination of 70 % was noticed up to four months only. Among the packaging materials, groundnut seed kernels stored in 700 gauge polyethylene bag showed better seed quality parameters viz., germination (60 %), root length (5.23 cm), shoot length (4.29cm), seedling vigour index (522), dehydrogenase enzyme activity (0.103 OD value) and lower electrical conductivity of seed leachate (1.127* dSm^{-1}*) after tenth months of storage as compared to 400 gauge polyethylene bag. The aim of the study was to determine the level of gaseous combination and storage containers on effective storage of groundnut seeds.*

Keywords: *modified atmospheric storage*, *dehydrogenase enzyme activity, vigour index, groundnut, germination*

1. Introduction

Groundnut (*Arachis hypogaea* L.) "King of oilseed crops", is believed to be native of Brazil (South America). It was introduced in India during first half of the sixteenth century. It belongs to the family leguminoceae (Fabaceae) and sub family papilonoceae. The cultivated form of groundnut has been classified into two major groups *viz*., valentia or Spanish type (*Arachis hypogaea* L. sub spp. festigata) and (*Arachis hypogaea* L. sub spp. hypogaea). It is a unique crop combining the attributes of both oil seed crop and legume crop in the farming system of Indian Agriculture. It is a valuable crop planted in dry areas of Asia, Africa, Central and South America, Australia and Caribbean in view of its economic, food and nutritional value.

Maintaining the quality of groundnut seed in post-harvest environment is demanding and often very difficult task. Most of the problems of maintainance of seed quality results from the methods used to harvest, store and process the peanuts. Damage from combining or from the equipment used in handling and processing operations, improper drying treatment, poor storage condition, inadequate protection from dirt mold, insects and rodents and similar causes of quality deterioration are very difficult to control or prevent. After the peanuts are shelled, controlling the quality deterioration becomes more difficult because the seeds are much more sensitive to condition and environments that causes loss of quality. Better methods and techniques are needed to improve conditions and environments that cause quality deterioration. A low-oxygen atmosphere system for handling peanut seed appears to be more potential for improving conventional practices.

Study of disinfestations of stored seeds using modified atmosphere storage (MA) involves the alteration of the natural storage gases such as carbon dioxide (CO_2), oxygen (O_2) and nitrogen (N_2) to render the atmosphere in the storage is lethal to pests. The MA includes neither the alteration of the storage atmosphere by addition of toxic gases such as phosphine or methyl bromide nor atmospheric water content. The MA may be achieved in several ways by adding gaseous or solid CO_2, by adding a gas of low O_2 content (*e.g.*, pure N_2 or output from a hydrocarbon burner) or by allowing metabolic processes within an airtight storage to remove O_2, usually with associated release of CO_2. Such an atmosphere is referred to as 'high-CO_2', 'low-O_2' and "hermetic storage' atmospheres, respectively. They are collectively known as 'modified atmospheres' (Banks and Fields, 1995). Modified atmosphere storage of seeds is a suitable alternative to the use of chemical fumigants and contact insecticides that are known to leave carcinogenic residues in the treated product (Bailey and Banks, 1980; Shejbal and Boislambert, 1988).

The most important component in MA is CO_2 which is a nonflammable, colourless gas which is about 1.5 times as heavy as air. Carbon dioxide can be supplied from an external source to a silo using either gas producer from liquid supplied in pressurized cylinders or from solid "dry ice". Solid "dry ice" useful source of CO_2 because it changes directly from solid to a gas. It can be supplied as blocks, crushed ice or pellets. Blocks are useful to make up gas loss during treatment due to their slower release. Crushed ice or pellets rapidly changes to a gas and are best for initial gas addition (Graver, 2004). Jayas and jeyamkondan (2002) reported that there are some different methods of introducing CO_2 as "dry ice" in the seeds mass in silo, they are as follows: (i) introducing of dry ice under the perforate floor or in the perforated duct (ii)introducing of dry ice on the top surface of the seeds covered with a CO_2 impermeable sheet (iii) introduction of equal amounts of dry ice on the top surface under the sheet and in the perforated duct (iv) introducing of dry ice through a 10cm—diameter perforated tube installed vertically in the center of the seeds bulk (v) introduction of one-quarter of the dry ice on the top surface under the sheet and the remaining three –quarter in an insulated box placed under the sheet. The fourth method gave the most uniform CO_2 concentration in the seeds mass and used the least amount of CO_2 to maintain the desired CO_2 concentration. However, installation of 10 cm diameter perforated tube would be very difficult therefore the last method was recommended for practical use (Alagusundaram *et al*., 1995a).

Recently, M/S Karnataka State Oilseeds Growers Federation Ltd., a leading groundnut seed producer in the state have ventured into the marketing of groundnut seed kernels instead of pods for seed production. If the seed kernels are not sold intime then it has to be carried to the next season, which definitely affects the seed viability due to soft seed coatedness. Besides, groundnut being inherently a short storer, the seed producing organization loooses precious seed materials as the kernel loose viability quickly compared to storing them with pods intact. Hence, it is necessary to explore suitable container and condition for storing of kernels.

2. MATERIAL AND METHODS

The laboratory experiments were conducted in the laboratory of department of seed science and technology, college of agriculture, university of agricultural sciences (UAS), Raichur during 2010-11 and packaging of the groundnut kernels was done in the department of processing and food engineering, college of agricultural engineering, UAS, Raichur with the modified atmosphere packaging equipment (MAP). TMV-2 is a Spanish bunch type cultivar derived by mass selection from 'Gundhiatham' bunch and released in the year 1946 at Tindivanam fir area like Tamil Nadu, Andra Pradesh and Karnataka which is widely adopted and well suited for both the seasons. It matures in 100-120 days. Hundred kernel weight is about 32.70 g and contains 49.00 percent oil. The seeds are light rose in colour. The shelling percentage is about 76.70 (Basu and Reddy, 1987). The experiment consisted of totally 26 treatment combinations along with two packaging materials [P1: Polyethylene bag (700 gauge) and P2: Polyethylene bag (400gauge)] and 13 gaseous treatments including control at ambient conditions.

Gaseous treatments:

T_0 : Control	
T_1 : 80 % N_2 : 20 % O_2 : 00 % CO_2	T_7 : 60 % N_2 : 10 % O_2: 30 % CO_2
T_2 : 80 % N_2 : 00 % O_2 : 20 % CO_2	T_8 : 60 % N_2 : 00 % O_2 : 40 % CO_2
T_3: 80 % N_2 : 10 % O_2: 10 % CO_2	T_9 : 50 % N_2 : 10 % O_2 : 40 % CO_2
T_4 : 70 %0. N_2 : 20 % O_2 : 10 % CO_2	T_{10} : 40 % N_2 : 20 % O_2 : 40 % CO_2
T_5 : 70 % N_2 : 10 % O_2 : 20 % CO_2	T_{11} : 20 % N_2 : 20 % O_2: 60 % CO_2
T_6 : 60 % N_2 : 20 % O_2 : 20 % CO_2	T_{12} : Vacuum

2.1 Method of Modified Atmosphere Packaging

Polythene bags of gauges 700 and 400 measuring 40 cm (length) and 25 cm (breadth) were used for packing purpose. In these bags, one kg ground nut seed kernels were packed along with the gases like CO_2, N_2 and O_2 in different concentrations according to the treatment. Firstly, the nozzel of the gas cylinders were opened and they were released at an pressure of 7kg/cm^2 and the different combinations of CO_2, N_2 and O_2 were mixed in the mixing chamber according to the treatments given and the gas flow rate was controlled in the buffer tank which is directly connected to the packing unit, where the groundnut kernels of one kg were packed in which the packaging machine first remove the air and then fill the gases of required combinations and automatically it will seal the packaging material. Change in gas concentration i.*e.*, O_2 and CO_2 were checked by check mate gas analyzer (plate 5) for that septum were stuck the cover, which avoids loss of gas from polyethylene bag while taking readings of change in gas concentration.

2.2 Procedure to use MAT instrument (plate-1)

First the concentration to the CO_2, O_2 and N_2 gas cylinder as in plate 1 with the mixing chamber has to be checked and the pressure of the gases adjusted so that the alarming red light in gas mixing chamber is switched off, later the required gas concentrations was to be adjusted as follows:

Adjust the top dial in the mixing chamber to the required CO_2 gas concentration and the value of the X (mentioned below the upper dial) is noted, then adjust the bottom dial by calculating the value (plate 2)

$$(N_2)/X$$

(N_2) = Nitrogen.

X = Value below the upper dial

b) The gas concentration has to be checked by using check mate gas analyzer (plate 2). From the gas sampling ports the gases were allowed to pass through the needle and the obtained gas concentration from the gas mixing chamber is checked.

c) If the required gas concentration is not achieved, then slightly change the dialer to get the exact required gas concentration and latter close the sampling port and vacate the buffer tank which is meant for collection and supply of gas in different gas concentration and gas combinations.

d) Buffer tank (Plate 3) has to be vacated so that the previous gas may lead to deviation in the required gas concentration and supply the gas through tube to modified atmosphere packaging instrument.

In packaging unit (plate 4), the heat of sealing adjusted to 2.0 to 2.5, so that the melting or improper sealing should be avoided. The packaging material (polyethylene, 700 and 400 gauge) kept in a packaging unit, where it first creates vacuum so that the old gas excavated from the packing material and it fills the required gas concentration from buffer tank and the packets sealed in that only.

2.3 Moisture Content (%)

Seed moisture content was determined using the low constant temperature oven method (ISTA, 2011) in two replicates of five grams seed material. The powdered seed material was placed in a weighed metal cup, and after removing the lid, moisture cups were placed in hot air oven maintained at 103 ± 2° C for 16 ± 1 h and the contents were allowed to dry. Moisture content was calculated as a percentage of fresh weight.

Further the seeds were observed for changes in various seed physiological parameters during storage. Germination test was conducted using four replicates of 100 seeds each in the paper (between paper) medium in the walk in germination room. The germination room was maintained at 25±1° C temperature and 90±2% RH.

2.4 Seed Germination (%)

A germination test was carried out following ISTA (2011), with four replicates of 100 seeds of each working sample. Final count (on tenth day) was taken based on number of normal seedlings in each replication and the germination was calculated and expressed in percentage. The seedling length was measured from tip of shoot to root tip and the mean length was calculated and expressed as seedling length in centimeters from the ten normal seedlings selected randomly from each treatment on the day of final count. The seedling vigour index was computed using the formula suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

2.5 Dehydrogenase Enzyme Activity (OD Value)

Representative seeds (25) from each treatment were taken and preconditioned by soaking in water overnight at room temperature. Seeds were taken at random and the embryos were excised. The embryos were steeped in 0.25 per cent solution of 2, 3, 5- triphenyl tetrazolium chloride solution and kept in dark for two hours at 40^0 C for staining. The stained seeds were thoroughly washed with water and then soaked in 10 ml of 2 methoxy ethanol (methyl celloslve) and kept overnight for extracting the red colour formazan. The intensity of red colour was measured using ELICO UV-VIS spectrophotometer (model SC-159) using blue filter (470 nm) and methyl cellosolve as the bank. The OD value obtained was reported as dehydrogenase activity (Kittock and Law, 1968)

2.6 Seed health test:

Storage fungi present on seeds were detected using blotter method as prescribed in ISTA (ISTA, 1999). Ten seeds were placed equidistantly on three layered moistened blotter taken in sterilized petriplate. Each treatment was replicated four times. They were incubated at 20°C for seven days with an alternate cycle of 12 hour near ultra violet (NVN) range and for remaining 12 hours in dark. On eighth day, the plates were examined under stereo binocular microscope for the presence of seed borne fungi. The number of infected seeds were counted and expressed in percentage.

3. Results

3.1 Moister Content

The mean moisture content increased at the initial stage from 5.7 to 6.16 (dSm-1) after ten months of storage, irrespective of modified atmospheric storage conditions and packaging materials. Among the modified atmospheric storage conditions there was no significant difference in all the months of storage. The packaging materials also didn't differ significantly with moisture content during all the months of storage.

3.2 Seed Germination (%)

The results of germination percentage as influenced by modified atmospheric storage conditions (MASC) and packaging materials during storage are presented in Table 1. With the advancement of storage period, the mean germination percentage declined from 93.00 per cent at the initial stage to 44.67 per cent at the end of storage period irrespective of modified atmospheric storage conditions and packaging materials and their interactions. Germination percentage due to MASC differs significantly in all the months of storage except for the second month irrespective of the modified atmospheric conditions. The seeds of treatment T8 recorded maximum germination of 62.67 per cent after ten months of storage period followed by T_{12} and T_2. The lowest germination of 45.17 per cent was noticed in T0 after ten months of storage. The seeds packed in 700 gauge polyethylene bag (P_1) with modified atmospheric storage conditions stored in polyethylene bag 700 gauges (P_1) recorded above the minimum seed certification standards (MSCS) of 70.03 per cent up to eight months followed by polyethylene bag 400 gauge (P_2) which was recorded 70.05 per cent up to six months of storage.

3.3 Seedling vigour index

The mean seedling vigour index decreased at the initial stage from 2688 to 325 after ten months of storage irrespective of modified atmospheric storage conditions and packaging materials. Significantly higher seedling vigour index-I of 574 was recorded in the seeds of T8 as compared to Control (333) at the end of storage period. The packaging materials have also differred significantly on seedling vigour index during all the months of storage. Seedling vigour index was significantly maximum in P_1 type of packaging material as compared to P_2 type at the end of storage period. In the beginning of storage, seedling vigour index was 2036 and 2009 in P_1 and P_2 types respectively, which were decreased to 522 and 441 respectively after the ten months of storage.

3.4 Dehydrogenase enzyme activity

The total dehydrogenase activity (TDH) declined with the advancement of storage period. Irrespective of modified atmospheric storage conditions and packaging materials and their interaction. The mean dehydrogenase activity decreased from 0.644 OD value at the initial stage to 0.064 OD value after ten months of storage irrespective of modified atmospheric storage conditions and packaging materials and their interactions. Significantly higher dehydrogenase activity of 0.103 OD value and 0.098 OD value respectively after ten months of storage.

The packaging materials also differed significantly on dehydrogenase enzyme activity during all the months of storage except for the second month of storage. Dehydrogenase activity was significantly maximum in 700 gauge polythene bag (P_1) compared to 400 gauge polythene bag (P_2) at the end of storage period. At the beginning of storage dehydrogenase enzyme activity were 0.544 OD value and 0.537 OD value in 700 gauge polythene bag (P_2) and 400 gauge polythene bag (P_2) respectively which decrease Significantly higher dehydrogenase activity of 0.133 OD value was recorded in the seeds exposed to 60% N_2+0 %O_2+40 % CO_2 compared to control (0.068 OD value) at the end of storage period.

3.5 Seed infection (%)

The data on seed infection as influenced by modified atmospheric storage conditions and packaging materials during storage are presented in Table. Seed infection increased with the advancement of storage period irrespective of modified atmospheric storage conditions and packaging materials and their interactions. The mean seed infection increased at the initial stage from zero to 17.80 % after ten months of storage irrespective of modified atmospheric storage conditions and packaging materials and their interactions. Modified atmospheric storage conditions differ significantly on seed infection during all the months of storage. The minimum seed infection was noticed in P1 type as compared to P2 type at the end of storage period. At the beginning of storage, seed infection were 1.20 % and 2.05 % in P1 and P2, respectively which increased to 11.45 % and 13.08 %, respectively after ten months of storage.

4. DISCUSSION

4.1 Influence of Packaging Materials on Storability of Groundnut

As the seed being hygroscopic in nature, it exhibit fluctuation in seed moisture content due to changes with atmospheric relative humidity and temperature. Therefore, it is essential to preserve kernels in suitable moisture proof containers which eliminate dampness, deterioration, micro-organisms and enhances the seed longevity. It is well known fact that the vapour proof packing is better to preserve the seeds in storage and seed has to be dried to a lower moisture level compared to packing in vapour pervious package. In the present study, all the seed quality parameters decreased with the advancement of the storage period. This may be due to natural ageing of the seeds, increased membrane permeability and seed borne mycoflora, resulting in increased electrical conductivity of the seed leachate. Significantly higher values for all the positive seed quality parameters were recorded in the seeds stored in P1 type packaging material than the seeds stored in P2 type. These results are in conformity with the reports of Basavaraju (1996), Shekargouda *et al.* (1998), Patra *et al.* (2000), Basavegouda and Ravikumar (2001) in groundnut.

The seeds stored in 700 gauge polyethylene bag were significantly superior in maintaining germination of seeds during the entire period as compared to the seeds stored in 400 gauge polyethylene bag. The germination of seeds stored in 700 gauge polyethylene bag (70.03%) recorded above the prescribed minimum seed certification standards (70.0%) up to eight months, whereas seeds stored in 400 gauge polyethylene bag were maintained the germination of (70.05%) up to six months only.

The seed kernels stored in 700 gauge polyethylene bag were recorded highest values for all the seed quality parameters compared to the seeds stored in 400 gauge polyethylene bag. The seed quality parameters like seed germination percentage (83.03 % - 62.67 %), root length (13.28 - 5.23 cm), shoot length (11.25 - 4.29 cm), seedling length (24.53 - 9.53 cm), seedling vigour index (2036.10 - 521.95), speed of germination (20.85 - 15.32), seedling dry weight (2.700 - 2.619 gm), test weight (34.46 - 34.07 gm), dehydrogenase activity (0.544 - 0.103 OD value) (Fig.3.), protein content (25.38 - 24.94 %) field emergence (80.08 - 52.41 %) (Fig. 2), oil content (47.07 % - 45.05 %), and lower electrical conductivity (0.0566 - 1.127 dSm^{-1}) (Fig. 4.), seed infection (1.28 - 11.45 %) (Fig. 5) and moisture content (5.82 - 6.09 %) were observed in 700 gauge polyethylene bag. The seeds stored in 700 gauge polyethylene bag maintained less moisture content due to the relative imperviousness nature. This is in agreement with the earlier study of Almeida *et al*. (1997) wherein they have revealed that maintenance of groundnut seed quality increased with impermeability of packaging.

The current study also revealed that the electrical conductivity values were inversely proportional to the germination percentage of seeds. Increased leaching of electrolytes was noticed in the seeds stored without modified atmospheric storage conditions (Control). Higher electrical conductivity of seed steep water might be due to its faster exudates that may be found in steep solution indicating faster deterioration. The weakening of cell membrane might have caused increased leaching of metabolites and electrolyte through the semi permeable membrane into the inhibiting medium (Chachalis and Smith, 2001).

4.2 Influence of modified atmospheric storage conditions on storability of groundnut

In the present study, the modified atmospheric storage conditions exhibited significant effect on seed germination of groundnut seed kernels. The seeds which were stored with the gaseous combination of 60 % N_2 + 0 % O_2 + 40 % CO_2 showed better germination throughout the storage period followed by the seeds stored under vacuum condition. At the end of the storage period the germination percentage was significantly higher in T_8 (62.67 %) followed by T_{12}, vacuum (61.67 %), T_2 (59.67 %).

Modified atmosphere storage of seeds devoid of oxygen showed retention of higher seed viability for an appreciable period. Both seed viability and vigour were well preserved with modified atmospheric storage particularly with carbon dioxide and vacuum conditions. The probable reason for differences in storability of seeds in the modified atmospheric storage condition might be due to the variation in the gas concentrations, where the treatment T8 having gas combination of higher CO_2 with zero percentage of oxygen concentration i.e., low oxygen atmosphere and also the seeds stored under vaccum condition showed better germination. Germination was reported to be decreased in peas with increase in oxygen level (Roberts and Abdalla, 1986a). Under the vaccum condition seed quality could be preserved even under higher temperature as reported by Brazalli et al., 2005.

In general, ageing is manifested by the decrease of metabolic activity and an increase of catabolic processes (Gorecki et al.,1996). In particular, an oxidative stress might be reduced in O_2- free storage atmospheres (Justice and Bass, 1978; Wilson Mcdonald, 1986; Benson, 1990). It should be noted that seed deterioration during storage could result in marked changes in the content and activity of enzymes capable for regarding the stored reserves (priestley,1986; smith and berjack, 1995; walters, 1998). In the present investigation it was observed that the dehydrogenase activity in the seed kernels was maximum due to, better maintanance of seed quality in modified atmospheric storage condition as compared to control. Another reason for seed ageing may be the accumulation of deleterious effects on membranes due to oxidative damages to fatty acids and protein denaturation as a result of maillard reactions (Narayana Murthy and Son, 2000). The advantage of higher seed reserve utilization efficiency in seeds stored in vacuum provide energy for a faster growing rate of the seedlings. In the present study also maximum speed of germination (15.68 and 15.61) was noticed in the treatment T_8 (60% N_2 + 0 % O_2 + 40 % CO_2) and T_{12} (vacuum), respectively. The similar result were also reported by Guillaumin (1928), Rathi et al., (2000), Bera et al., (2004), and Bera et al., (2008).

Another advantage of low oxygen method is that the moisture content of peanut seed stored in the container does not change very much. A similar study by slay et al (1985) also indicated that up to 20 % less storage space is required for the low oxygen method.

The germination (62.67 %), root length (5.11 cm), shoot length (4.43 cm), seedling length (9.48 cm), vigour Index (574), seedling dry weight (2.674 gm), dehydrogenase activity (0.133 OD value), speed of germination (15.68), were significantly higher in seeds stored under treatment T8 with lower moisture content (6.06%), EC value (1.093 dSm^{-1}) and 9.44 percent of seed infection were observed when compared with other treatments. Whereas all these parameters were lowest in seeds stored in control i.e. without modified atmospheric storage condition.

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Table 1. *Influence of modified atmospheric storage condition and packaging materials on moisture content (%) of groundnut seed kernels during storage*

Treatment	Months of storage (Aug-2010 to April-2011)				
	2	4	6	8	10
Modified atmospheric storage conditions (T)					
T_0 : Control	5.88	5.90	5.95	6.01	6.16
T_1 : 80 % N_2 : 20 % O_2 : 00 % CO_2	5.83	5.85	5.91	5.98	6.10
T_2 : 80 % N_2 : 00 % O_2 : 20 % CO_2	5.80	5.82	5.88	5.95	6.07
T_3: 80 % N_2 : 10 % O_2: 10 % CO_2	5.83	5.85	5.91	5.98	6.10
T_4 : 70 % N_2 : 20 % O_2 : 10 % CO_2	5.84	5.86	5.92	5.99	6.11
T_5 : 70 % N_2 : 10 % O_2 : 20 % CO_2	5.82	5.84	5.89	5.97	6.09
T_6 : 60 % N_2 : 20 % O_2 : 20 % CO_2	5.82	5.84	5.90	5.97	6.09
T_7 : 60 % N_2 : 10 % O_2: 30 % CO_2	5.82	5.84	5.89	5.97	6.09
T_8 : 60 % N_2 : 00 % O_2 : 40 % CO_2	5.79	5.81	5.87	5.94	6.06
T_9 : 50 % N_2 : 10 % O_2 : 40 % CO_2	5.81	5.83	5.89	5.96	6.08
T_{10} : 40 % N_2 : 20 % O_2 : 40 % CO_2	5.84	5.86	5.92	5.99	6.11
T_{11} : 20 % N_2 : 20 % O_2: 60 % CO_2	5.87	5.89	5.94	6.02	6.14
T_{12} : Vacum	5.81	5.83	5.88	5.96	6.08
Mean	5.83	5.85	5.90	5.98	6.10
SEm±	0.0365	0.0364	0.0367	0.0371	0.0362
CD(5%)	NS	NS	NS	NS	NS
Packaging materials(P)					

P_1 : Polyethylene bag (700 gauge)	5.82	5.84	5.89	5.97	6.09
P_2: Polyethylene bag (400 gauge)	5.84	5.86	5.92	5.99	6.11
Mean	5.83	5.85	5.90	5.98	6.10
SEm±	0.0149	0.0143	0.0144	0.0145	0.0142
CD (5%)	NS	NS	NS	NS	NS

NS-Non significant

Table 2. *Influence of modified atmospheric storage conditions and packaging materials on germination (%) of groundnut seed kernels during storage*

Treatment	**Months of storage (Aug-2010 to April-2011)**				
	2	4	6	8	10
Modified atmospheric storage conditions (T)					
T_0 : Control	81.17(64.29)*	73.83(59.21)	63.33(52.71)	56.17(48.52)	45.17(42.21)
T_1 : 80 % N_2 : 20 % O_2 : 00 % CO_2	82.17(65.02)	75.00(59.99)	70.50(57.16)	64.83(53.65)	54.50(47.58)
T_2 : 80 % N_2 : 00 % O_2 : 20 % CO_2	84.83(67.08)	77.83(61.92)	75.33(60.24)	71.17(57.60)	59.67(50.58)
T_3: 80 % N_2 : 10 % O_2: 10 % CO_2	83.33(65.93)	75.83(60.53)	70.83(57.32)	66.67(54.74)	56.17(48.53)
T_4 : 70 % N_2 : 20 % O_2 : 10 % CO_2	83.17(65.79)	76.83(61.22)	70.00(56.80)	65.83(54.24)	56.00(48.44)
T_5 : 70 % N_2 : 10 % O_2 : 20 % CO_2	82.17(65.04)	76.50(60.99)	70.00(56.78)	65.83(54.23)	56.50(48.72)
T_6 : 60 % N_2 : 20 % O_2 : 20 % CO_2	81.50(64.53)	75.00(59.99)	68.50(55.86)	66.00(54.32)	55.67(48.25)
T_7 : 60 % N_2 : 10 % O_2: 30 % CO_2	84.00(66.44)	80.50(63.79)	74.83(59.89)	69.00(56.15)	57.00(49.01)
T_8 : 60 % N_2 : 00 % O_2 : 40 % CO_2	86.00(68.05)	83.33(65.90)	78.33(62.26)	73.67(59.18)	62.67(52.35)
T_9 : 50 % N_2 : 10 % O_2 : 40 % CO_2	81.00(64.16)	79.00(62.70)	75.33(60.22)	68.17(55.63)	57.00(49.01)
T_{10} : 40 % N_2 : 20 % O_2 : 40 % CO_2	80.17(63.56)	76.83(61.22)	72.00(58.05)	68.00(55.63)	56.67(48.82)
T_{11} : 20 % N_2 : 20 % O_2: 60 % CO_2	81.50(64.53)	77.50(61.69)	75.33(60.22)	68.33(55.74)	57.00(49.01)
T_{12} : Vacum	83.83(66.31)	83.17(65.77)	78.83(62.60)	72.83(58.63)	61.67(51.74)
Mean	82.68	77.78	72.55	67.42	56.59
SEm±	1.021	0.436	0.270	0.273	0.253
CD(5%)	NS	1.238	0.765	0.776	0.718
Packaging materials(P)					
P_1 : Polyethylene bag (700 gauge)	60.00(47.49)	79.00(62.06)	75.05(60.08)	70.03(56.86)	60.03(47.53)
P_2: Polyethylene bag (400 gauge)	82.36(65.20)	76.56(61.08)	70.05(56.86)	64.82(53.63)	53.15(46.78)
Mean	82.68	77.78	72.55	67.42	56.59
SEm±	0.401	0.171	0.106	0.107	0.099
CD (5%)	1.137	0.485	0.300	0.304	0.282

NS-Non significant

*Figures in the parenthesis represent arcsine values

Table 3. *Influence of modified atmospheric storage conditions and packaging materials on seeding vigour index of groundnut seed kernels during storage*

Treatment	**Months of storage (Aug-2010 to April-2011)**				
	2	4	6	8	10
Modified atmospheric storage conditions (T)					
T_0 : Control	1913	1369	921	561	333
T_1 : 80 % N_2 : 20 % O_2 : 00 % CO_2	1997	1476	1070	703	464
T_2 : 80 % N_2 : 00 % O_2 : 20 % CO_2	2094	1554	1221	805	484
T_3: 80 % N_2 : 10 % O_2: 10 % CO_2	2048	1510	1110	743	483
T_4 : 70 % N_2 : 20 % O_2 : 10 % CO_2	2048	1536	1090	732	471
T_5 : 70 % N_2 : 10 % O_2 : 20 % CO_2	2013	1520	1102	743	467
T_6 : 60 % N_2 : 20 % O_2 : 20 % CO_2	1994	1479	1058	716	464
T_7 : 60 % N_2 : 10 % O_2: 30 % CO_2	2060	1604	1186	758	498
T_8 : 60 % N_2 : 00 % O_2 : 40 % CO_2	2133	1688	1290	908	574
T_9 : 50 % N_2 : 10 % O_2 : 40 % CO_2	1982	1557	1198	765	498
T_{10} : 40 % N_2 : 20 % O_2 : 40 % CO_2	1954	1514	1121	737	482
T_{11} : 20 % N_2 : 20 % O_2: 60 % CO_2	1983	1532	1184	742	478
T_{12} : Vacum	2075	1676	1294	902	565
Mean	2023	1541	1142	755	482
SEm±	26.74	11.88	7.70	6.09	4.46
CD(5%)	NS	33.71	21.86	17.30	12.65
Packaging materials(P)					
P_1 :Ppolyethylene bag (700 gauge)	2036	1593	1197	804	522
P_2:Ppolyethylene bag (400 gauge)	2009	1489	1087	706	441
Mean	2023	1541	1142	755	482
SEm±	10.49	4.66	3.02	2.39	1.74
CD (5%)	29.77	13.22	8.57	6.78	4.96

NS-Non significant

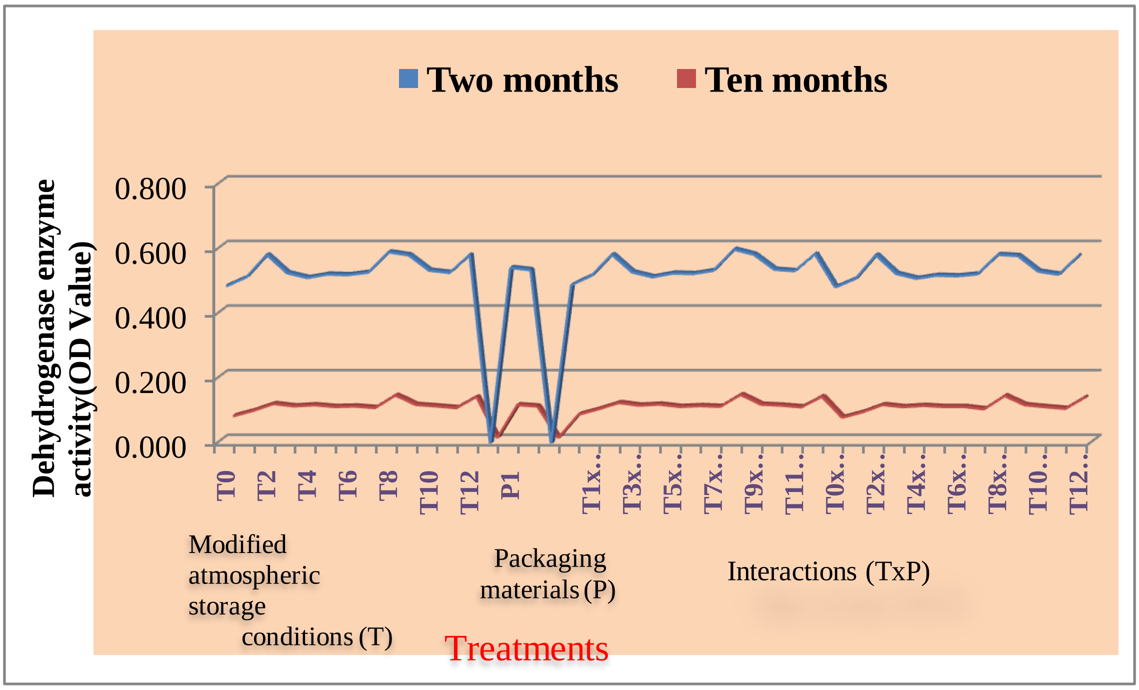

Fig. 1. *Influence of modified atmospheric storage conditions, packaging materials and their interactions on dehydrogenase activity (OD value) of groundnut seed kernels during storage*

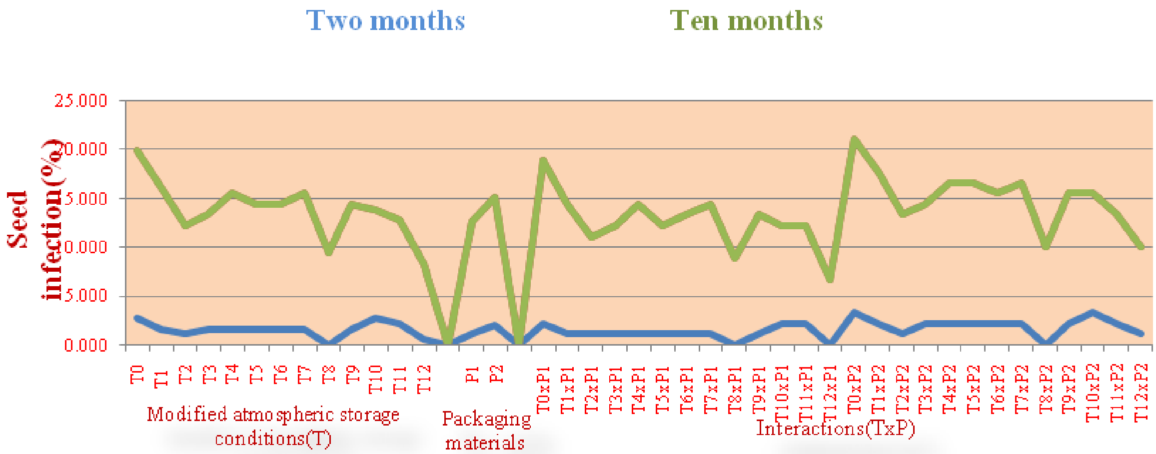

Fig. 2. *Influence of modified atm Fig. 2. Influence of modified atmospheric storage conditions, packaging materials and their interactions on seed infection (%) of groundnut seed kernels during storage.*

Ospheric Storage Conditions, Packaging

Plate 1: Cylinders with mixing chamber

Plate 2: Mixing chamber

Plate 3: Buffer tank

Plate 4: Packaging unit

Plate 5: Checkmate gas analyzer

Plate 6: Modified Atmosphere Packaging Instrument

Plate 8: Vacuum and Normal packaging of groundnut seed kernels

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