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Seed viability and seed health as influenced by modified atmospheric gases condition on Kabuli chickpea (*Cicer arietinum* L.) varieties

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Abstract
The present investigation was carried out at Seed Quality and Research Laboratory, National Seed Project, University of Agricultural Sciences, Dharwad from March 2017 to May 2018 to know the effect of modified atmospheric gases on seed viability and seed health of kabuli chickpea varieties. The results of study revealed that modified atmospheric gaseous combinations of CO_2 (80%) + N_2 (20%) + O_2 (0%) (C_2) recorded significantly highest seed germination (92.38 %) with zero per cent of seed infestation and seed infection compared to control (C_1) (88.75 %, 9.38 % and 29.49 %, respectively) at the end of 14 months of storage. Further, this technology can be used an alternative to chemicals which is safe, ecofriendly for maintaining quality of organically produced seed and its longevity during storage.

Keywords: Carbon dioxide, nitrogen, oxygen, seed infection, seed infestation, vaccum

Introduction

Chickpea (*Cicer arietinum* L.) is an old world pulse crop commonly known as Bengalgram, garbanzo bean, gram, Chana, Kadlee and is the third most important pulse crop in the world after beans and peas. Chickpea is popularly cultivated in sub tropical and semi-arid to warm temperate regions under dry season. Chickpea is valued for its nutritive seed composition with high protein content and used increasingly as a substitute for animal protein. Chickpea is predominantly consumed in the form of whole grain or dhal, sprouted grain, green or matured dry seeds and is used in the preparation of variety of snacks, sweets and condiments. It has highly digestible protein (21.1 %), carbohydrates (61.5 %) and fats (4.5 %). Further, it also accounts for efficient soil enrichment by symbiotic nitrogen fixation and it has ability to meet more than 70 per cent of its nitrogen requirement from symbiotic nitrogen fixation, besides being drought tolerant (Bahl and Salimath, 1996) [4].

Chickpea is classified based on seed size, shape and colour. Two main types of chickpea cultivars grown globally are Kabuli and Desi, representing two diverse gene pools. The two most commonly cultivated types *viz.,* white seeded 'Kabuli chickpea' being grown in Northern parts and brown seeded 'Desi' type grown in Southern parts of India. Kabuli types are categorized into three groups based on seed size *viz*., large-seeded, medium seeded and small-seeded. In Asia, India is the largest producer of chickpea contributing over 70 per cent of the world production occupying an area of 86.80 lakh hectare with a production of 80.90 lakh tonnes and with productivity of 932 kg per hectare (Anon., 2017) [3]. The major chickpea growing states in India are Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Andhra Pradesh and Karnataka. In Karnataka state, Gulbarga, Bidar, Bijapur, Dharwad, Bellary and Raichur are the major chickpea growing districts covering an area of 1.37 millon hectare with a production of 0.90 millon tonnes and the productivity is 654 kg per hectare (Anon., 2017) [3]. Globally and nationally the area, production and productivity of Kabuli chickpea is very low as compared to Desi type chickpea due the fragile seed coat of Kabuli chickpea.

Seed storage is an integral part of well planned and timely executed seed programme for maintenance of high quality seeds in terms of germination, vigour and health. During storage considerable qualities and quantities of seeds are lost due to biotic factors like storage pests specially bruchids, other mycoflora and abiotic factors like temperature, moisture content, and relative humidity. In order to prevent qualitative and quantitative seed losses in storage, various prophylactic methods are being adopted in many agricultural crops i.e. by treating seeds with suitable botanicals and pesticides.

But new alternative method of seed treatment is the need of hour because of preference of consumer towards kabuli chickpea for table purpose and confectionary uses. Hence, seed storage and its quality maintenance becomes more challenging in Kabuli chickpea seeds as, they are more susceptible to infestation of pulse beetle and storage fungi. A low-oxygen atmosphere system for handling of chickpea seeds appears to have potential for improving storage practices. Many studies have showed that modified atmosphere of elevated carbon dioxide and depleted oxygen is an effective method against insect, pests and microorganisms attack during storage. Modified atmosphere storage is one of the best method to store seeds that maintains the natural quality of seeds besides extending the storage life of seed by reducing the respiration rate of seed and is an alternative method to avoid chemical fumigants, which are said to cause residual effect on seed material and development of resistance by storage pest against insecticides and pesticides. Alternatively high carbon dioxide treatment is residue free and approved by Environmental Protection Agency, USA. Carbon dioxide treated seeds are also accepted in the organic market. Hence, an attempt was made to know the effect of modified atmospheric gases on seed viability and seed health of kabuli chickpea varieties.

Materials and Methods

The seeds were packed in 700 gauge polyethylene bags at the Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur using the Modified Atmosphere Packaging (MAP) Unit (Plate 1) in order to know the seed viability and seed health of Kabuli chickpea by subjecting to different modified atmospheric storage conditions with different combination of gases like nitrogen, carbon dioxide and oxygen at different concentrations. The experiment consisted of two varieties *viz.*, V_1 (BG1105) and V_2 (MNK-1) and five treatments *viz.*, C_1: Normal air (untreated control), C_2: CO_2 (80 %) + N_2 (20 %) + O_2 (0 %), C_3: CO_2 (75 %) + N_2 (20 %) + O_2 (5 %), C_4: CO_2 (70 %) + N_2 (20 %) + O_2 (10 %) and C_5: Vaccum packing. The seeds were packed as per the treatment combination and stored for 14 months under ambient condition at Dharwad. The experiment was carried out in Completely Randomised Design with four replications and observations on various seed quality parameters were recorded bimonthly at the Seed Quality and Research Laboratory (NSP), University of Agricultural Sciences, Dharwad.

Method of modified atmosphere packaging

Polyethylene bag (700 gauge) measuring 25 cm length and 15 cm breadth were used for packing purpose. In these bags, 800 gram of chickpea seeds of both varieties were packed along with the gases like carbon dioxide, nitrogen and oxygen in different concentrations according to the treatments. The valves of the gas cylinders were opened and released at a pressure of 7 kg/cm^2 and the different combinations of carbon dioxide, nitrogen and oxygen were mixed in the mixing chamber as per treatment combination. Further, gas flow rate was controlled in the buffer tank which was directly connected to the packaging unit. The chickpea seeds of 800 grams were packed using the packaging machine (Plate 1e) by evacuating the air, then flushing with the gases of required combinations followed by sealing automatically. Composition of the gas *i.e.*, O_2 and CO_2 gas concentrations inside the package was checked by Check mate head space gas analyser (Plate 1f) with the help of septum which prevents leakage of gas from polyethylene bag.

Procedure to use MAP instrument (Plate 1g)

The cylinders containing Carbon dioxide (CO_2), Oxygen (O_2) and Nitrogen (N_2) gas (Plate 1a) were checked for the pressure and the pressure of the gases was adjusted by following the steps detailed below.

a) The top dial in the mixing chamber was adjusted to the required CO_2 gas concentration and the value of X (mentioned below the upper dial) was noted then adjusted the bottom dial by calculating the value of N_2/X (Plate 1b and 1c). Where,
   N_2 = Nitrogen gas concentration
   X = Number below the upper dial
b) The desired gas concentrations were checked by using check mate gas analyze through the gas sampling port the gases were allowed to pass through needle and the gas concentration in gas mixing chamber was recorded (Plate 1b and 1c).
c) If the required gas concentration was not achieved then dialer was tuned to get the exact gas concentration. The sampling port was closed the gas present in the buffer tank was evacuated.
d) Buffer tank (Plate 1d) needed to be evacuated to achieve required gas concentration. The gas was supplied through tube to modified atmosphere packing unit for packaging of seeds.

In packaging unit (Plate 1e) the heat level of sealing adjusted to 2.00 to 2.50 to achieve proper sealing. The packaging material (polyethylene, 700 gauge) was kept in a packaging unit in which the vacuum was created by evacuating air present in the packing material and then filled the required gas concentration from buffer tank and sealed.
The seeds obtained from each treatment were evaluated for the following seed quality parameters in the Seed Quality and Research laboratory, Seed Unit, University of Agricultural Sciences, Dharwad.

Germination test: The test was conducted using eight replicates of 50 seeds by paper towel method and incubated in the walk in seed germination room maintained at 25 ± 1°C temperature and 90 ± 1 % relative humidity. The number of normal seedlings in each replication was counted at the end of 8 days and the mean germination percentage (%) was calculated (ISTA, 2013) [2].

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds}} \times 100$$

Seed mycoflora (Seed infection): Detection and identification of seed mycoflora was done by blotter paper method (TP) as per ISTA (Anon, 2011) [1]. Twenty five seeds of two replications were placed equidistantly in sterile glass petridishes of 9 cm diameter containing three moist blotter papers (Whatman No.1). Then the petridishes were incubated at 20^{0}C for 7days with alternate 12 hours light and 12 hours dark. After incubation, seeds were examined under stereo binocular microscope for the presence of seed infection. The seed number of seeds infected were recorded and expressed as percentage of infection.

Insect damage (Seed infestation): One hundred seeds from each treatment and in four replications were taken to determine the insect (*Callosobruchus chinensis*) infestation level in chickpea seeds. The seeds either with egg spot or single or multiple holes were considered as infested seeds. Infested seeds were counted manually and expressed in percentage (Anon., 2011) [1]. The data collected from the experiments were analyzed statistically by the procedure prescribed by Gomez and Gomez (2010) [9].

Results and Discussion

Influence of kabuli chickpea varieties on seed quality: In general, influence of modified atmospheric storage conditions had profound effect on seed longevity and quality of Kabuli chickpea varieties. Seed quality differs among the varieties in a crop. Among the varieties, significantly higher seed germination (99.10 %), moisture content (6.99 %), seed infection (0.00 %) and infestation (0.00 %) was recorded in variety V_1 (BG1105) as compared to variety MNK-1 (98.10 %, 7.24 %, 0.00 %, 0.00 %, respectively). However, there was gradual decrease in seed quality with the advancement of storage period.

Similar trend was followed throughout the storage period, whereas at the end of fourteen months of storage V_1 (BG1105) recorded significantly highest seed germination (91.40 %), (Table 1), seed moisture content (7.90 %) (Table 2), seed infection (6.90 %) (Table 3) and infestation (2.06 %) (Table 4) as compared to MNK-1 (V_2) (90.10 %, 8.36 %, 14.95 % and 5.15 %, respectively). This may be attributed to genotypic response of varieties, where V_1 (BG1105) was superior over MNK-1 (V_2). Similar varietal response was reported by Merwade (2000) [15] and Gnyandev (2009) [8] in chickpea.

Influence of modified gaseous on seed quality in Kabuli chickpea genotypes

The modified atmospheric storage conditions exhibited significant effect on seed germination of chickpea seeds. The seeds which were stored with the gaseous combination of CO_2 (80 %) + N_2 (20 %) + O_2 (0 %) (C_2) showed better germination throughout the storage period followed by the gaseous combination of vaccum packing (C_5) and CO_2 (75 %) + N_2 (20 %) + O_2 (5 %) (C_3) and lowest in control. The seed germination per cent due to concentrations of modified atmospheric gases varied significantly at all the month of storage period except for initial month. From second month of storage period significantly highest seed germination (99.88 %) was recorded in C_2 (80 % CO_2: 20 % N_2: 0 % O_2) treated seeds and it was followed by C_5 (vaccum treated seeds) (99.38 %), while the lowest (95.75 %) was recorded in untreated seeds (control) (C_1). At the end of fourteen months of storage period the highest seed germination was recorded in C_2 (92.38 %) and it was followed by C_5 (91.63 %) and the lowest was recorded in control (C_1) (88.75 %). Whereas, in the initial month numerically highest germination was recorded (99.88 %) in C_2 and the lowest (99.88 %) in control (Table 1).

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 condition. The probable reason for differences in longevity of seeds in the modified atmospheric storage conditions may be due to the variation in the gas concentrations, where the treatments C_2 and vaccum packing having gas combination of higher CO_2 with zero per cent of oxygen concentration *i.e.*, low oxygen atmosphere and also the seeds stored under vacuum condition showed better germination. Germination was reported to decrease in peas with increase in oxygen level (Roberts and Abdalla, 1968) [18]. Under the vacuum condition seed quality could be preserved even under higher temperature as reported by Barzali *et al*. (2005) [5].

In general, ageing is manifested by decrease of metabolic activity and an increase of catabolic processes (Gorecki *et al*., 1996) [10]. In particular, an oxidative stress might be reduced in oxygen free storage atmospheres (Justice and Bass, 1978; Wilson McDonald, 1986; Benson, 1990) [13, 22, 6]. It should be noted that seed deterioration during storage could result in marked changes in the content and activity of enzymes capable for degrading the stored reserves (Priestley, 1986) [17]. Another reason for seed ageing may be the accumulation of deleterious effects on membranes due to oxidative damages to fatty acids and proteins denaturation as a result of maillard reactions (Narayana Murthy and Sun, 2000) [16]. The advantage of higher seed reserve utilization efficiency in seeds stored in low oxygen concentration and vacuum packing, provide energy for a faster growing rate of the seedlings.

Another advantage of low oxygen method is that the moisture content of chickpea seed stored in the container does not change very much. A similar study by Slay *et al.* (1985) [21] also indicated that up to 20 per cent less storage space was required for the low oxygen method. The moisture content of seed plays a major role in determination of seed storability (Copeland and Mcdonald, 1995) [7]. Similarly in the present study also the lowest moisture content (8.03 %) of seeds was recorded in C_2 (80 % CO_2: 20 % N_2: 0% O_2) treated seed followed by C_5 (vaccum packing) (8.11 %). While, the highest moisture content of seeds was recorded in control (8.42 %) at the end of fourteen months of storage period (Table 2).

Regarding the effect of the modified atmospheric storage conditions the lowest insect damage per cent (0.00) was noticed in the treatment C_2 after fourteen months of storage (Table 3). The reduction in insect activity might be due to high CO_2 content which is relatively more toxic for all developmental stages of *Callosobruchus maculatas* than low CO_2 content. The atmosphere containing low concentration of oxygen was more toxic in the shorter exposure period (Hashem and Reichmuth, 1996) [12]. Another important issue related to insect disinfestation is the lack of oxygen, which is called anoxia. Lack of oxygen is a major reason for insect mortality; it increases the acid level in the form of lactic acid and causes poisoning (Mbata and Reichmuth, 1996) [14]. Similarly, lowest seed infection (0.00 %) was recorded in C_2 (80 % CO_2: 20 % N_2: 0% O_2) treated seed followed by C_5 (vaccum packing) (0.00 %) (Table 4). While, the highest seed infection was recorded in control (29.49 %) at the end of fourteen months of storage period. Similar findings were also reported by Gupta *et al.* (2014) [11] in rice, Shivappa (2011) [19] in onion and Shrishail (2011) [20] in groundnut. However, the seed quality parameters did not differ significantly due to interaction of varieties and concentrations of modified atmospheric gases at all the months of storage period.

Table 1: Influence of modified atmospheric storage conditions on germination in Kabuli chickpea varieties during storage

Treatments	Germination (%)							
	Months of storage							
	0	2	4	6	8	10	12	14
Varieties								
V_1 -BG1105	99.10 (84.52)*	98.55 (83.05)	97.75 (81.34)	96.80 (79.66)	95.90 (78.29)	95.55 (77.79)	93.40 (75.08)	91.40 (72.92)
V_2 -MNK-1	98.15 (82.15)	97.95 (81.74)	97.00 (79.99)	95.75 (78.07)	94.75 (76.72)	94.45 (76.34)	91.75 (73.28)	90.10 (71.63)
S. Em. ±	**0.41**	**0.14**	**0.18**	**0.24**	**0.29**	**0.28**	**0.29**	**0.29**
C. D. @ 1 %	**NS**	**0.53**	**0.71**	**0.92**	**1.11**	**1.07**	**1.12**	**1.11**
Concentration of modified atmospheric gases (C)								
C_1: Normal air (untreated control)	96.63 (79.39)	95.75 (78.07)	94.25 (76.10)	94.00 (75.79)	93.13 (74.77)	92.50 (74.08)	90.38 (71.90)	88.75 (70.37)
C_2: CO_2 (80%) + N_2 (20%) + O_2 (0%)	99.88 (87.98)	99.88 (87.98)	99.00 (84.23)	97.88 (81.60)	97.00 (79.99)	96.88 (79.79)	94.25 (76.10)	92.38 (73.95)
C_3: (75%) + N_2 (20%) + O_2 (5%)	99.00 (84.23)	98.63 (83.24)	97.88 (81.60)	96.50 (79.19)	95.63 (77.90)	95.38 (77.56)	92.88 (74.49)	91.00 (72.51)
C_4: CO_2 (70%) + N_2 (20%) + O_2 (10%)	98.13 (82.11)	97.63 (81.11)	97.38 (80.65)	95.88 (78.26)	94.75 (76.72)	94.50 (76.41)	92.00 (73.54)	90.13 (71.66)
C_5: Vaccum packing	99.50 (85.91)	99.38 (85.45)	98.38 (82.65)	97.13 (80.21)	96.13 (78.62)	95.75 (78.07)	93.38 (75.06)	91.63 (73.15)
S. Em. ±	**0.65**	**0.21**	**0.29**	**0.37**	**0.45**	**0.44**	**0.46**	**0.45**
C. D. @ 1 %	**NS**	**0.83**	**1.12**	**1.45**	**1.75**	**1.69**	**1.77**	**1.76**
Interaction (V x C)								
V_1C_1	98.00 (81.84)	96.50 (79.19)	94.75 (76.72)	93.75 (75.49)	94.00 (75.79)	93.75 (75.49)	91.50 (73.02)	89.50 (71.06)
V_1C_2	100.00 (89.96)	100.00 (89.96)	99.50 (85.91)	98.75 (83.55)	97.50 (80.87)	97.25 (80.42)	95.00 (77.05)	93.00 (74.63)
V_1C_3	99.00 (84.23)	98.50 (82.93)	98.25 (82.37)	97.25 (80.42)	96.50 (79.19)	96.00 (78.43)	94.00 (75.79)	92.00 (73.54)
V_1C_4	98.75 (83.55)	98.00 (81.84)	97.50 (80.87)	96.50 (79.19)	95.25 (77.38)	95.00 (77.05)	92.75 (74.35)	90.75 (72.26)
V_1C_5	99.75 (87.10)	99.75 (87.10)	98.75 (83.55)	97.75 (81.34)	96.25 (78.80)	95.75 (78.07)	93.75 (75.49)	91.75 (73.28)
V_2C_1	95.25 (77.38)	95.00 (77.05)	93.75 (75.49)	94.25 (76.10)	92.25 (73.81)	91.25 (72.76)	89.25 (70.83)	88.00 (69.70)
V_2C_2	99.75 (87.10)	99.75 (87.10)	98.50 (82.93)	97.00 (79.99)	96.50 (79.19)	96.50 (79.19)	93.50 (75.20)	91.75 (73.28)
V_2C_3	99.00 (84.23)	98.75 (83.55)	97.50 (80.87)	95.75 (78.07)	94.75 (76.72)	94.10 (75.91)	91.75 (73.28)	90.00 (71.54)
V_2C_4	97.50 (80.87)	97.25 (80.42)	97.25 (80.42)	95.25 (77.38)	94.25 (76.10)	94.00 (75.79)	91.25 (72.76)	89.50 (71.06)
V_2C_5	99.25 (85.00)	99.00 (84.23)	98.00 (81.84)	96.50 (79.19)	96.00 (78.43)	95.75 (78.07)	93.00 (74.63)	91.25 (72.76)
Mean	**98.63**	**98.25**	**97.38**	**96.28**	**95.33**	**94.94**	**92.58**	**90.75**
S. Em. ±	**0.92**	**0.30**	**0.41**	**0.53**	**0.64**	**0.62**	**0.64**	**0.64**
C. D. @ 1 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*Figures in the parenthesis are arcsine root transformed values, NS: Non-significant

Table 2: Influence of modified atmospheric storage conditions on moisture content in Kabuli chickpea seeds during storage

Treatments	Moisture content (%)							
	Months of storage							
	0	2	4	6	8	10	12	14
Varieties								
V_1 -BG1105	6.99	7.01	7.07	7.12	7.34	7.58	7.90	7.96
V_2 -MNK-1	7.24	7.31	7.53	7.58	7.81	8.04	8.36	8.43
S. Em. ±	**0.06**	**0.02**	**0.04**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
C. D. @ 1 %	**0.23**	**0.07**	**0.17**	**0.08**	**0.08**	**0.08**	**0.09**	**0.08**
Concentration of modified atmospheric gases (C)								
C_1: Normal air (untreated control)	7.30	7.33	7.53	7.58	7.81	8.04	8.36	8.42
C_2: CO_2 (80%) + N_2 (20%) + O_2 (0%)	6.98	7.01	7.14	7.19	7.41	7.65	7.97	8.03
C_3: (75%) + N_2 (20%) + O_2 (5%)	7.10	7.13	7.25	7.30	7.53	7.76	8.08	8.14
C_4: CO_2 (70%) + N_2 (20%) + O_2 (10%)	7.22	7.25	7.37	7.42	7.65	7.88	8.20	8.26
C_5: Vaccum packing	6.96	7.09	7.21	7.26	7.49	7.72	8.04	8.11
S. Em. ±	**0.09**	**0.03**	**0.07**	**0.03**	**0.03**	**0.03**	**0.04**	**0.03**
C. D. @ 1 %	**NS**	**0.11**	**0.27**	**0.13**	**0.12**	**0.12**	**0.15**	**0.13**
Interaction (V x C)								
V_1C_1	7.11	7.13	7.31	7.36	7.58	7.82	8.14	8.20
V_1C_2	6.92	6.94	6.97	7.02	7.24	7.48	7.80	7.86
V_1C_3	6.94	6.96	6.99	7.04	7.26	7.49	7.81	7.88
V_1C_4	7.06	7.08	7.11	7.16	7.38	7.62	7.94	8.00
V_1C_5	6.92	6.94	6.97	7.02	7.24	7.48	7.80	7.86
V_2C_1	7.49	7.53	7.75	7.80	8.03	8.26	8.58	8.65
V_2C_2	7.05	7.09	7.31	7.36	7.59	7.82	8.14	8.20
V_2C_3	7.26	7.29	7.52	7.57	7.79	8.02	8.34	8.41
V_2C_4	7.37	7.41	7.63	7.68	7.91	8.14	8.46	8.52
V_2C_5	7.01	7.23	7.46	7.51	7.73	7.97	8.29	8.35
Mean	**7.11**	**7.16**	**7.30**	**7.35**	**7.58**	**7.81**	**8.13**	**8.19**
S. Em. ±	**0.13**	**0.04**	**0.10**	**0.05**	**0.04**	**0.04**	**0.05**	**0.05**
C. D. @ 1 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS: Non-significant

Table 3: Influence of modified atmospheric storage conditions on seed insect damage in Kabuli chickpea seeds during storage

Treatments	Seed insect damage (%)							
	Months of storage							
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**
Varieties								
V_1 -BG1105	0.00	0.00	0.00	0.00	0.10	0.71	1.56	2.06
V_2 -MNK-1	0.00	0.00	0.00	0.00	0.63	2.31	3.90	5.15
S. Em. ±	**0.00**	**0.00**	**0.00**	**0.00**	**0.13**	**0.32**	**0.50**	**0.69**
C. D. @ 1 %	**0.00**	**0.00**	**0.00**	**0.00**	**0.51**	**1.23**	**1.95**	**2.69**
Concentration of modified atmospheric gases (C)								
C_1: Normal air (untreated control)	0.00	0.00	0.00	0.00	1.25	4.16	7.25	9.38
C_2: CO_2 (80%) + N_2 (20%) + O_2 (0%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_3: (75%) + N_2 (20%) + O_2 (5%)	0.00	0.00	0.00	0.00	0.56	1.50	2.63	3.51
C_4: CO_2 (70%) + N_2 (20%) + O_2 (10%)	0.00	0.00	0.00	0.00	0.00	1.91	3.78	5.13
C_5: Vaccum packing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S. Em. ±	**0.00**	**0.00**	**0.00**	**0.00**	**0.21**	**0.50**	**0.79**	**1.09**
C. D. @ 1 %	**0.00**	**0.00**	**0.00**	**0.00**	**0.80**	**1.94**	**3.09**	**4.25**
Interaction (V x C)								
V_1C_1	0.00	0.00	0.00	0.00	0.50	1.56	3.50	4.50
V_1C_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_1C_3	0.00	0.00	0.00	0.00	0.00	0.75	1.75	2.53
V_1C_4	0.00	0.00	0.00	0.00	0.00	1.25	2.56	3.25
V_1C_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_2C_1	0.00	0.00	0.00	0.00	2.00	6.75	11.00	14.25
V_2C_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_2C_3	0.00	0.00	0.00	0.00	1.13	2.25	3.50	4.50
V_2C_4	0.00	0.00	0.00	0.00	0.00	2.56	5.00	7.00
V_2C_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	**0.00**	**0.00**	**0.00**	**0.00**	**0.36**	**1.51**	**2.73**	**3.60**
S. Em. ±	**0.00**	**0.00**	**0.00**	**0.00**	**0.29**	**0.71**	**1.12**	**1.55**
C. D. @ 1 %	**0.00**	**0.00**	**0.00**	**0.00**	**NS**	**NS**	**NS**	**NS**

NS: Non-significant

Table 4: Influence of modified atmospheric storage conditions on seed mycoflora in Kabuli chickpea seeds during storage

Treatments	Seed mycoflora (%)							
	Months of storage							
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**
Varieties								
V_1 -BG1105	0.00	0.00	0.00	0.23	0.34	2.31	5.27	6.90
V_2 -MNK-1	0.00	0.00	0.00	1.29	1.47	4.86	11.28	14.95
S. Em. ±	**0.00**	**0.00**	**0.00**	**0.23**	**0.26**	**0.58**	**1.28**	**1.40**
C. D. @ 1 %	**0.00**	**0.00**	**0.00**	**0.90**	**1.02**	**2.26**	**4.99**	**5.43**
Concentration of modified atmospheric gases (C)								
C_1: Normal air (untreated control)	0.00	0.00	0.00	2.52	2.85	8.35	22.83	29.49
C_2: CO_2 (80%) + N_2 (20%) + O_2 (0%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_3: (75%) + N_2 (20%) + O_2 (5%)	0.00	0.00	0.00	1.28	1.68	4.19	7.32	9.78
C_4: CO_2 (70%) + N_2 (20%) + O_2 (10%)	0.00	0.00	0.00	0.00	0.00	5.31	10.54	14.29
C_5: Vaccum packing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S. Em. ±	**0.00**	**0.00**	**0.00**	**0.37**	**0.42**	**0.92**	**2.03**	**2.21**
C. D. @ 1 %	**0.00**	**0.00**	**0.00**	**1.43**	**1.62**	**3.57**	**7.89**	**8.59**
Interaction (V x C)								
V_1C_1	0.00	0.00	0.00	1.14	1.68	6.12	14.64	18.80
V_1C_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_1C_3	0.00	0.00	0.00	0.00	0.00	2.04	4.76	6.87
V_1C_4	0.00	0.00	0.00	0.00	0.00	3.40	6.97	8.84
V_1C_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_2C_1	0.00	0.00	0.00	3.90	4.02	10.58	31.02	40.19
V_2C_2	0.00	0.00	0.00	0.00	0.00	0.18	1.41	2.12
V_2C_3	0.00	0.00	0.00	2.55	3.35	6.35	9.87	12.69
V_2C_4	0.00	0.00	0.00	0.00	0.00	7.23	14.10	19.74
V_2C_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	**0.00**	**0.00**	**0.00**	**0.76**	**0.90**	**3.59**	**8.28**	**10.92**
S. Em. ±	**0.00**	**0.00**	**0.00**	**0.52**	**0.59**	**1.30**	**2.87**	**3.12**
C. D. @ 1 %	**0.00**	**0.00**	**0.00**	**NS**	**NS**	**NS**	**NS**	**NS**

NS: Non-significant

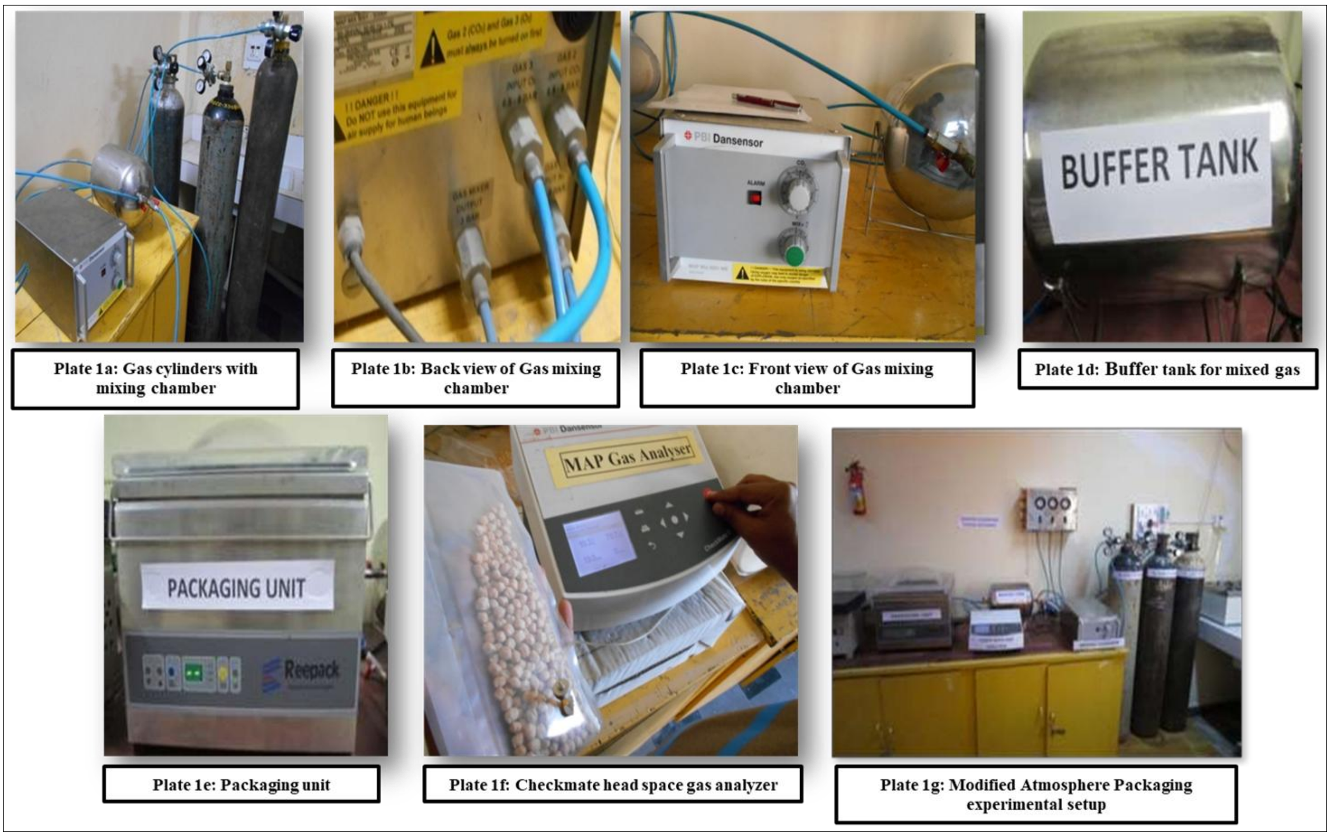

Plate 1: General view of modified atmosphere packaging (MAP) Unit

Conclusion

The results of study revealed that all modified atmospheric gaseous combinations viz., C_2 [CO_2 (80%) + N_2 (20%) + O_2 (0%)], C_3 [CO_2 (75%) + N_2 (20%) + O_2 (5%)], C_4 [CO_2 (70%) + N_2 (20%) + O_2 (10%)] and C_5 [Vaccum packing] maintained seed viability above Indian Minimum Seed Certification Standards (IMSCS) for 14 months. Further, this technology can be used an alternative to chemicals which is safe, ecofriendly particularly beneficial in the absence of cold storage facility and in addition it can be used for maintaining quality of organically produced seeds and its storability.

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