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Vacuum packaging as novel approach to extend storability and quality of various crop seeds

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Abstract
The choice of a packaging material for any agricultural produce differs with the type of markets in which the products are distributed. In developing countries, this choice is largely determined by the cost and availability of packaging materials. Seed storage is an integral part of seed production programme. Seeds of many field crops are produced with greater care and cost. Hence, a good storage is essential to keep them alive and vigorous until required for subsequent sowing season. Seed is said to be in storage in various stages from harvest to sowing. Further the left over seeds are to be stored without appreciable decline in quality in order to meet the further demand. Generally, seeds stored in moisture impervious sealed containers stored better compared to moisture pervious containers under ambient storage as well as cold storage conditions. The prevailing relative humidity and temperature of the atmosphere influence greatly the longevity of seeds, since moisture content of seeds fluctuates more in moisture pervious containers than in moisture vapour proof containers. The packaging materials used are decided by kind and quantity of seed to be packed, the type of package, duration of storage, storage temperature and relative humidity of the storage area, etc. The studies of vacuum packaging are therefore expected to address some of these problems and thus maintain quality of agricultural produce for a relatively longer period over traditional packaging and extending the shelf life, seed storability and seed quality of the same.

Keywords: Vacuum Packaging, Shelf life, Quality and Traditional packaging

Introduction
Storage seeds are an important problem from the time mankind learnt to grow crops. Million tons of seeds are either damaged or lost due to inadequacy of scientific methods of storage. Post-harvest losses of seeds in storage are very substantial and such losses thwart our attempt to boost agricultural production and maintain self-sufficiency in seeds. The primary cause leading to loss in quality and quantity of agricultural produce during its storage is due to presence of higher moisture content in the stocks at the time of storage cause sprouting, molding and heating. Insects and rodents apart from eating away the produce pollute it by contamination with their urine, excreta and carcass. Insects and mites eat away the germ portion of the seeds rendering it unfit for germination and impart objectionable odor. These losses can be avoided by using modern techniques based on scientific storage (Anon., 2010) [4]. The present survey was deals with seed deterioration during storage and the vacuum packaging is a good approach to avoid the same.

Storage of seeds till the next sowing season is an essential segment of seed industry. The knowledge of seed storability is also essential to avoid the huge financial losses due to non-selling of the seeds and to carry over the seed stock for use in next season. Storage is a critical operation for rice, representing between 4 to 6 per cent of total post-harvest losses. In rice, upon storage, many enzymatic changes, oxidation and respiration occur. Thus, its nutritive value is lost because of chemical changes in starch, protein and lipid contents. If the viability and vigour is not maintained properly during storage period, it will be difficult to sell it as a seed material for the next season. Post-harvest storage life of rice largely depends on the genotypes, production conditions, mechanical injury to the seed, initial seed quality, seed treatment, packaging material and storage conditions. Seed storage is an essential segment of seed industry. In storage, viability and vigour of the seeds is regulated by many physico-chemical factors like moisture content of the seed, atmospheric humidity, and temperature, and initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure and packaging materials. As the seed is hygroscopic in nature, seed quality is affected by variation in moisture content, relative humidity and temperature.

To combat these factors, it is better to store the seeds in moisture vapour proof containers like vacuum packaging bags, polythene bags, aluminium foil, tin or any sealed container to maintain the quality for longer period.

Packaging is an important part of product processing and preservation and has direct influence on the system in respect to physical and chemical changes. Plastic materials are used very widely for food packaging application because of their obvious advantages of being light in weight, having good productivity, can be manufactured into a number of forms and shape and being recyclable [Narayanan and Dordi, 1998] [27]. Though packing is the last step in the post-harvest operations, it is one of the most important contributors to the value of the produce. It plays an important role in the export, because foreign buyer expects the goods to be received in good condition. It also protects the contents from the external environmental variables ensures full retention of the utility value of the product and prevents loss and damage. The factors causing deterioration in foods are: (i) inherent properties of the food which cannot be prevented by packaging and (ii) properties which are dependent on environment and are possible to control by the type of packaging employed [Ranganna, 1986] [31].

One of the most important properties of flexible packaging materials is the degree to which they are able to resist the passage of gases and vapour. The mechanisms by which gases and vapour permeate through the packaging materials are:

1. The presence of macroscopic pores and canals as in paper- based materials like kraft paper and vegetable parchment.
2. By the process of solution of the gas at one surface of the film, diffusion through the main bulk of it, and evaporation from the other surface (as in uncoated cellulose, polyethylene and cellulose acetate) and
3. The presence of pinholes as in aluminum foils [Ranganna, 1986] [31].

Packaging of seeds in flexible films and laminates is comparatively a recent practice and has been mainly due to the functional advantages of the flexible films like transparency, protection against moisture ingress, reduction in wastes, prevention of adulteration, etc. besides increasing the shelf-life [Mahadevaiah *et al.*, 1976] [25]. In the packaging of dry food products, most important considerations are protection from moisture pick up, oxidation and loss of volatile gases. Exposure to light, high temperature, mechanical damage and flavouring constituents may also cause problems (Ranganna, 1986) [31].

2. Vacuum Packaging

Vacuum packaging is removing air from the product pouch and hermetically sealing it. This increases storage or shelf life by inhibiting the growth of microorganisms and improves hygiene by reducing the danger of cross contamination. Vacuum packing also preserves flavour and protects against dehydration and weight loss (Anon., 2006a) [6].

a) Advantages of vacuum packaging

- A simple solution to packaging goods requiring protection from oxygen
- Positive control of the moisture content of the produce
- Inhibits the growth of aerobic spoilage bacteria
- Lower costs than those of rigid containers
- Longer shelf life for goods

b) Disadvantages of vacuum packaging

- It is virtually impossible to remove all the oxygen, since small quantities will be trapped within food cells.
- Microorganisms which are not affected by oxygen are not advantageously affected by vacuum packing.

3. Seed storability & quality

3.1 Seed storability

In stored seeds, ageing is universal physiological phenomenon followed by deterioration resulting in loss of viability. Usually it progress at a faster rate under stress or unfavorable conditions. The mechanism of deterioration which is the stage of ageing process is still an enigma. The potential storage life of seeds varies from species to species [Harrington, 1960 and Agrawal, 1980] [43, 8] and within a species from variety to variety [Agrawal, 1979] [8]. The causes for deterioration in storage life of seeds of different species are not fully understood. The expression of seed quality in seed lot is influenced by a set of interacting components resulting from genetic makeup, seed development, harvest and storage conditions [Ching, 1982] [13]. Roberts [1972] [33] postulated loss of viability due to intrinsic and extrinsic factors. The most important factors that determine the longevity of seeds in storage are the seed moisture, temperature, relative humidity and the type of container. Storing and preserving of quality seeds until the next season is as important as producing quality seeds.

Storage potential, storage life, life span, or period of viability refers to the length of time required for a certain percentage of the seeds to die or conversely for a certain percentage to live. Storage potential of an individual seed is affected by genetic effects, pre-harvest effects, seed structure and composition, hard seeds, seed dormancy, seed maturity, seed size, seed moisture content, mechanical damage and seed vigor. Different seeds have different storage potential. Even within the same crop or the same variety, seed quality may be different depending on storage environment, *i.e.* temperature, seed moisture content and relative humidity, interrelationship of temperature, seed moisture content and storage life, vacuum and gas storage, illumination, and respiration and heating [Justice and Bass, 1979] [22]. Oxidation of food ingredients like vitamins, pigments and aroma compounds is one of the most important causes of quality loss during food processing and is the main deteriorative reaction in microbiologically safe foods like dry and frozen products [Anderson and Lingnert, 1997] [3]. Since air contains 21% oxygen, it is a potent and a major force in accelerating oxidation of the stored product packed in containers. If the containers are packed with little or no air space above the product, the oxidation can be avoided [Anon., 2000a] [5]. Oxygen sensitive foods should thus be stored in packages with initial contents of head space oxygen below 2% to ensure long shelf life [Rooney *et al.*, 1983] [34]. The growth of aerobic microorganisms is supported by oxygen, thus removal of oxygen from the modified atmosphere has been shown to extend the microbiological shelf life [Sanjeev and Ramesh, 2006] [35]. Deterioration is a universal phenomenon in any living beings, which involves a series of changes and finally ends with death of seeds. In seed this process is the result of a organism complex interaction of time, environmental factors, intrinsic constituents and mechanisms in the seed itself.

Copeland (1985) [15] highlighted the consequences of deteriorative changes in seed which include membrane degradation, accumulation of toxic metabolites, decreased enzymatic activity, lipid auto-oxidation, and failure of repair mechanisms, genetic degradation, and reduced yield, finally loss of germination or death. The main factors are responsible for major physiological and biochemical manifestation of seed deterioration *viz*., change in relative humidity, temperature, membrane degradation, enzyme activity, changes in chemical constituents as well.

3.2 Seed quality

Seed quality is a limiting factor affecting, not only germination capacity but also emergence potential, field stand and uniformity, seedling growth and finally crop productivity. The significance of seed quality is more pronounced under adverse seed sowing conditions. Seed quality (seed viability and vigor) has a profound effect on seed performance, stand establishment and ultimately economical yield. Seed vigor refers to the ability and strength of a seed to germinate successfully and produce normal seedling and optimum field stand under both optimum and suboptimal soil conditions and therefore, to maximize yield. Seed vigor is gradually acquired as the seed develops on the parent plant reaches maximum at the physiological maturity stage. Conditions inhibiting normal plant growth, seed development and maturation can reduce the maximum attainable vigor. Following physiological maturity, seed vigor is readily declined till being seeded in the growing season or as seed deterioration progress by means of physical, physiological and pathogenic deteriorative processes [Copeland and McDonald, 1985] [15].

Vacuum packaging refers to the technology wherein the product to be packed is placed in a pouch of suitable material and air is drawn out from the pack prior to the final sealing. Low oxygen contents are usually obtained by removal of air using evacuation and/or inert gas flushing before sealing the package [Rooney *et al*., 1983] [34]. Vacuum packaging is the simplest and the most common means of modifying the internal gaseous atmosphere in a pack. The product is placed in a pack made from film of low oxygen permeability. Air is evacuated and the package is sealed. An evacuated pack collapse around the product so that the pressure inside is seldom much less than atmosphere [Kothari and Jadhav, 1998] [23]. Vacuum packaging and gas flushing are techniques adopted for the purpose of prevention of food spoilage by oxidation. Elimination of oxygen from the pack therefore helps in extending the shelf life of the products. These methods are effectively utilized for packaging processed food products such as tea, coffee, cheese, snack foods, nuts, etc. [Narayanan and Dordi, 1998] [27].

Many properties of foods such as microbiological status, insect infestation, and chemical degradation such as rancidity, pigment/nutrient loss and browning and physiological changes such as, respiration are influenced by oxygen level in the headspace of the packaging materials. Removal of oxygen from the headspace has long been a target and this has manifested in the development of technologies such as, vacuum packaging and inert gas flushing [Singhal and Kulkarni, 1998] [38]. Vacuum packaging is removing air from the product pouch and hermetically sealing it. This increases storage or shelf life by inhibiting the growth of microorganisms and improves hygiene by reducing the danger of cross contamination. It also preserves flavour and protects against dehydration and weight loss [Anon., 2006 a] [6]. Oxidation of food ingredients like vitamins, pigments and aroma compounds is one of the most important causes of quality loss during food processing and is the main deteriorative reaction in microbiologically safe foods like dry and frozen products [Anderson and Lingnert, 1997] [3]. Since air contains 21% oxygen, it is a potent and a major force in accelerating oxidation of the stored product packed in containers. If the containers are packed with little or no air space above the product, the oxidation can be avoided [Anon., 2000a] [5]. Oxygen sensitive foods should thus be stored in packages with initial contents of head space oxygen below 2% to ensure long shelf life [Rooney *et al*., 1983] [34]. The growth of aerobic microorganisms is supported by oxygen, thus removal of oxygen from the modified atmosphere has been shown to extend the microbiological shelf life [Sanjeev and Ramesh, 2006] [35]. A vacuum of 91.75 k Pa results in 2.09% residual oxygen and 97.929 k Pa vacuum leaves 0.69% residual oxygen. Therefore, in order to obtain a residual oxygen content of less than 1%, a vacuum of better than 95 k Pa is required [Eselgroth, 1951] [20]. Under good vacuum condition, the oxygen level is reduced to less than 1% and due to the barrier properties of the film used; entry of oxygen from outside is restricted. Commercial vacuum systems used on production lines do not reach absolute vacuum and there is always some residual oxygen present (0.3-3% after sealing). Hence, the gaseous atmosphere of the vacuum package is likely to change during storage (owing to microbial and product metabolism and gas permeation) and therefore, the atmosphere becomes modified [Sanjeev and Ramesh, 2006] [35].

Seed quality (seed viability and seed vigor) is a limiting factor affecting, not only germination capacity but also emergence potential, field stand, uniformity, seedling growth and finally crop productivity. The significance of seed quality is more pronounced under adverse seed sowing conditions. Seed vigor refers to the ability and strength of a seed to germinate successfully and produce normal seedling and optimum field stand under both optimum and suboptimal soil conditions and therefore, to maximize yield. Seed vigor is gradually acquired as the seed develops on the parent plant reaches maximum at the physiological maturity stage. Conditions inhibiting normal plant growth, seed development and maturation can reduce the maximum attainable vigor. The various seed quality related findings of researchers have been suggested that vacuum packaging is better over conventional packaging and extending the storability & quality of same are listed in the following Table.

Sl. No.	Name of the Researchers	Crops	Seed Quality Parameters
1.	Pandiarajan *et al.* [1994] [29]	Banana	Bunches could be stored in a vacuum pack at room temperature for up to 3 weeks
2.	Ada *et al.* [2003] [1]	Potato	The physical qualities of minimally processed potatoes (Desiree variety) stored for 7-10 days under vacuum packaging
3.	Sharma *et al.* [2006] [37]	Cashew kernels	Vacuum packaging of fried cashew kernels treated with antioxygenic salt extended the shelf life and acceptability up to one year, irrespective of frying medium under ambient conditions

4.	Gorris and Peppelenbos [1992] [21]	Unripe Banana	It was found that vacuum packing of green unripe banana could prolong the shelf life of banana to more than 40 days
5.	Rouziere [1986] [30]	Peanuts	No changes in physico-chemical properties occurred during high vacuum storage at any temperature or quality of peanuts during nitrogen compensated vacuum storage at ambient temperature, over a period of 18 months
6.	Beirne and Alison [1987] [12]	Potato	Enzymatic discolouration in potato strips could be reduced considerably by vacuum packaging with dipping in ascorbic acid based antioxidant solutions and storing at 5ºC. Vacuum packaged strips had retained excellent colour for at least 14 days either without antioxidant or with 1 per cent or 5 per cent ascorbic acid.
7.	(Steinbuch *et al.*, 1980) [41]	Green Vegetables	Vacuum packaging also contributed to a prolonged maintenance of original flavour of the leaves of herbs. Both the flavour and colour of the sliced celeriac was preserved by vacuum packing for one month.
8.	Sheik *et al.* [1985] [39]	Groundnut	Vacuum and nitrogen gas replacement treatments in packaging of peanuts inhibited rancidity development. They also reported that the use of free oxygen absorbers produced anaerobic conditions for about 90 days and thus inhibited fungal growth and rancidity.
9.	Balasubramanyam *et al.* [1983] [10]	Peanuts	Vacuum packaging extending shelf life upto 180 days normal conditions
10.	Slay *et al*. [1980] [40]	Peanuts	The shelf life of peanuts in plastic packages could be increased from a few weeks to several months by purging the packs with nitrogen gas under vacuum.
11.	Dull and Kays [1988] [18]	Pecan kernel	Vacuum packaging maintained colour and greatly reduced the mechanical damage in pecan kernels
12.	Achour *et al*. [2003] [2]	Datepalm	The application of partial vacuum packaging increased shelf life from 3.8 to 9 months compared to simple sealing
13.	Severini *et al*. [2003] [36]	Almond	Vacuum conditions were necessary for the successful preservation of roasted almonds, but the effectiveness of vacuum was apparent only if it is combined with a good oxygen barrier provided by the selected packaging film
14.	Chiu *et al*. [2003] [14]	Sweet corn	Primed sweet corn seeds were vacuum-packed and stored at 25 °C up to 12 months
15.	Barzali *et al*. [2005] [11]	Rye seeds	Vacuum packed seeds gave the highest values for shoot dry weight, seedling dry weight, shoot length, root length, and seedling length
16.	Sanjeev and Ramesh [2006] [35]	Packaged food	Although vacuum or gas packaging can be used to extend the shelf life and keeping quality of food
17.	Ellis and Hong [2007] [19]	Sesame	The deleterious effect of oxygen on seed longevity increases as seed moisture content decreases and confirmed that hermetic(Vacuum) packaging is preferable for long-term seed storage
18.	Rao and Sastry [2002] [32]	Sorghum & Bajara	There was a gradual loss in germination rate under vacuum packed bags under all the storage conditions
19.	Paakkonen *et al*. [1989] [28]	Dill	Freeze dried dill was better preserved in vacuum packages at room temperature compared to glass jars and paper bags and was found to have higher intensity of odour and taste
20.	Mohamed *et al*. ([1996] [26]	Chiku	The ascorbic acid content was highest in vacuum packed fruits
21.	Meena, M.K. & Chetti, M.B. (2015) [24]	Onion	The vacuum packed onion seeds indicating better seed quality parameters over conventional packed seeds upto 18 months of storage
22.	Chetti, M.B. & Meena, M.K. (2015) [24]	Onion, cotton, Peanut & soybean	Results of the study revealed that there was a gradual decline in seed quality parameters of all crops during entire storage period of 18 months with respects to vacuum packed seeds.

Conclusion
Farmers, traders normally pack the seeds of various crops in either polythene bags, gunny bags or cloth bags before being used for propagation in the next season. Many seeds loose viability during the storage due to their sensitivity to oxidation and variation in moisture content during the storage period. It has been found that storing the fruits, vegetables and dry fruits under vacuum packed bags enhance the shelf life while maintaining the quality. Since the seed is an essential input in agriculture, it is utmost necessary to maintain the viability and Vigour of the seed. Many a times, it so happens that the good quality seed is not available to the farmers in time due to various reasons, the average productivity of most of the crop plants has gone down Considerably in the last one decade and one of the reasons for such decline is the poor quality of seeds being used by the farmers. Vacuum packaging has been found to be superior technology in preserving the seed quality of different field crops. Despite the fact that vacuum packaging literally means a system without air, no vacuum packaging technique has been successful in creating a perfect vacuum. Even in the present study, it is inferred that the trapped air in the bulk of different crops seeds accounted for the observed deterioration of quality parameters even though it was only to a slight extent.

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