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A REVIEW

# Impact of vacuum packaging on various seed quality and biochemical parameters of different spice crops

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## SUMMARY

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 material. The situation, however, changes totally for spices that are marketed internationally where the main criterion is that the product has to be preserved and protected during handling and storage, and throughout extended transport and distribution networks. Dry spices though microbiologically safe when compared to the fresh produce, are not safe from oxidation of carotenoid pigments. Studies on vacuum packaging are, therefore, expected to address some of these problems and thus maintain quality for a relatively longer period. The main quality contributing factors of spices *viz.,* aroma, flavour and colour are sensitive to the vagaries of climate and are affected by factors like high temperature and humidity, moisture and oxygen, respiration and heating, insects, pests and microorganisms, which work together in causing deterioration. Traditionally, storage of spices in warehouse is done with a jute bag, Double gunny bags, multi wall paper sack or cotton bags are also being used for better protection. But these have the problem of moisture ingress, oxidation and subsequent quality loss. In case of dry whole chilies, due to low bulk density, volume poses a problem, which becomes a crucial factor in shipments and exports.

**Key Words :** Vacuum packaging, Dry spices, Flavour, Aroma, Colour, Shelf life, Quality deterioration, Traditional packaging

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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). Though it 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 development of exports, because the foreign buyer expects the goods to be received in good condition. It also protects the contents from the environment and vice-versa, in order to ensure full retention of the utility value of the product and to prevent loss, damage and theft (Douglas *et al.*, 2005). The factors causing deterioration in foods are (i) inherent properties of the food which can not 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).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: i) The presence of macroscopic pores and canals as in paper- based materials

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like kraft paper and vegetable parchment., ii) 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, iii) The presence of pinholes as in aluminum foils.

Packaging of chillies, both whole and ground, 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). In the packaging of dry food products, the 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 .

**Vacuum packaging :**

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).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. 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).

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 (Anonymous, 2006 a).The average family throws away approximately $1200 worth of spoiled food each year. Vacuum packaging can eliminate most of this cost when used properly. Vacuum packaged foods maintain their freshness three to five times longer than food stored by conventional methods. There are other secondary benefits of vacuum packaging. Many products shift violently during the shipment process and cause the products to be damaged. Vacuum packaging hugs the product in place, thwarting this violent movement and thus having the following distinct advantages (Anonymous, 2006 b). i) Extends shelf life, aids in controlling oxidative rancidity and prevents the growth of normal spoilage bacteria ,ii) Reduces moisture loss and freeze burn., iii) Package is drawn tight around the product, taking minimal space for storage, iv)Leakages are easily detected. A small puncture or pinhole in a vacuum pack is easy to detect by looking for loose packages. Foods maintain their freshness and flavour 3-5 times longer than with conventional storage method, as they don't come in contact with oxygen. Insect infestation is eliminated, because insects require oxygen to survive and hatch. 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, 1983).

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). Since air contains 21per cent 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 (Anonymous, 2000). Oxygen sensitive foods should thus be stored in packages with initial contents of head space oxygen below 2 per cent to ensure long shelf life. 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). A vacuum of 91.75 kPa results in 2.09 per cent residual oxygen and 97.929 kPa vacuum leaves 0.69 per cent residual oxygen. Therefore, in order to obtain a residual oxygen content of less than 1per cent, a vacuum of better than 95 kPa is required (Eselgroth, 1951). Under good vacuum condition, the oxygen level is reduced to less than 1per cent 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).

**Influence of vacuum packaging on seed quality parameters:**

*Aroma and flavour* :

Controlled experiments were carried out by storing cocoa beans under vacuum for one year period using the technique of capatainerisation which is vacuum packaging in bulk developed for powdery or granular material that at present has to be stocked and transported in sacks, barrels or even loose, thus, overcoming the many disadvantages in cost, loss, damage and pollution that these traditional methods involve. It was reported that the application of vacuum had totally eliminated insect larvae found in normally stored beans, namely *Ephestia cautella, Stephanoderes hampel, Ahasverus* sp. and *Araccerus fasciculatus*. The initial moisture content of 7.3 per cent was not modified and organoleptic tests revealed that flavour had improved due to aroma development. It was also seen that there was a limited development of white mold, *Geotrichum* which is frequently found on cocoa (Anonymous, 1977). Steinbuch (1980) studied the quality retention of unblanched frozen vegetables by vacuum packaging in asparagus, parsley and celery. Results indicated the favourable effect of vacuum packaging on quality retention, resulting in a long shelf life. Vacuum packing did contribute to a prolonged maintenance of original flavour of parsley leaves.

Experiments by Slay *et al*. (1980) on shelled peanuts revealed that quality grades and germination were better maintained in a 26 Hg vacuum or 26 vacuum with back flash to 16 Hg than in ambient or refrigerated conditions. While, Sheikh *et al*. (1985) studied the quality preservation of peanuts by means of plastic packaging and revealed that vacuum treatments inhibited rancidity development. Rouziere (1986) stored three peanut varieties using high vacuum or nitrogen – compensated vacuum packaging for 18 months at $6^0$C and at room temperature and observed no changes in physico-chemical properties under nitrogen compensated vacuum storage at room temperature. Beirne and Alison (1987) examined the possibility of preventing enzymatic discolorations in potato strips by combining vacuum packaging with dipping in ascorbic acid based antioxidant solutions and storing at $5^0$C. They reported that vacuum packaged strips retained excellent colour for at least 14 days either without antioxidant or with 1per cent or 5 per cent ascorbic acid compared to control. After 14 days of storage, strips dipped in 1 per cent ascorbic acid and vacuum packaged had substantially lower microbial counts. Studies of Dull and Kays (1988) revealed that vacuum packed pecan kernels maintained the colour and greatly reduced the mechanical damage.

Paakkonen *et al*. (1989) studied the effect of drying method, packaging and storage temperatures and time on the quality of dill (*Anethum graveolens* L.) and concluded that 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. Locatelli and Traversa (1989) evaluated the efficiency of vacuum packaging for controlling the insects and found that a vacuum of 93.3 kPa eliminated *Cryptolestes ferrugineus, Oryzaephilus surinamensis, Sitophilus granaries, S. oryzae, Colydium castaneum, Corcyra cephalonica, Ephestia cautella, E. kuehniella* and *Plodia interpunctella*, common storage insects in groundnut, bran, maize, flour and rice. The usual vacuum level of 69.3 kPa permitted the survival of eggs of *S. oryzae* after 7 weeks and a high level of *O. surinamensis* and *Colydium castaneum* after 4 days. While, other species studied were eliminated at vacuum of 69.3 kPa for 4 days.

**Extended shelf life :**

According to Sattar *et al*. (1990) and Senesi *et al*. (1991), it is possible to extend the shelf life of nuts by using packaging materials with high barrier effect against gas and / or light or modified atmospheres inside the package. Gorris and Peppelenbos (1992) described a moderate vacuum packing system for fresh produce, in which the atmospheric pressure in a rigid storage container was reduced to 400 mbar by evacuating the air from the container. This system was found to extend the shelf life of fresh produce and prevent enzymatic browning of cut fruits and vegetables. Studies also showed that the shelf life of green Rasthali plantain could be increased to more than 40 days. Pandiarajan *et al*. (1994) also reported that vacuum packaging of Rasthali banana fruits delayed ripening, reduced weight loss and restricted mechanical damage during transport and storage and makes it possible to improve the quality of banana.

The effect of modified atmospheric packaging on the physico-chemical characteristics of chiku (*Achras sapota* L.) at various storage temperatures was studied by Mohamed *et al*. (1996) and found that the ascorbic acid content was highest in vacuum packed fruits. An absence of air in vacuum packed fruits restricted the oxidation of ascorbic acid in addition to minimum pathogenic spoilage. Anonymous (2000) concluded that vacuum packaging system could be used to package and preserve dried green coffee beans. The applied packaging film had enough barrier properties to provide a small, acceptable increase in oxygen and water content in the headspace of the package necessary for water activity of the green Columbian coffee beans, stored in extreme climatic condition ($30^0$C and 90% RH) over 6 months. Severini *et al*. (2003) studied the autooxidation of packed roasted almonds as affected by two packaging films and found that 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. Achour *et al*. (2003) studied the effect of vacuum and modified atmosphere packaging on the storage of Deglet Nour date and found decreased dehydration during storage under both the conditions. For natural dates stored at less than $20^0$C, the application of partial vacuum packaging increased shelf life from 3.8 to 9 months compared to simple sealing.

**Moisture content and oxidation :**

Spices deteriorate rapidly under adverse conditions and should be stored in well maintained storage facilities. It is essential that the moisture level of the spice to be stored is at a safe level, usually below 10 per cent moisture to ensure storage without mold growth (Douglas *et al*., 2005).Water activity ($a_w$), the amount of water present in dehydrated foods, affects several degradative reactions in foods, such as non enzymatic browning, lipid oxidation, vitamin degradation, enzyme activity, microbial activity and pigment stability (Hardman, 1976; Leung, 1987). Certain amount of moisture content is required in many dehydrated foods for optimum storage stability. Salwin (1959) stated that maximum storage stability occurs at moisture contents corresponding to $a_w$ values between 0.2 and 0.4. Moisture may protect carotenoids from oxidation through a direct effect on the free radicals produced during pigment oxidation. In paprika, high moisture levels (10-14%) retard colour loss while low moisture levels (< 8%) accelerate pigment destruction (Chen and Gutmanis, 1968; Carbonell *et al*., 1986 and Lee *et al*., 1992). Increased moisture content decreases the number of free radicals and thereby slows the oxidation rate of carotenoids (Labuza *et al*., 1970).

Kanner *et al*. (1977) found that the colour deterioration was lower at high moisture contents (10-14%) with corresponding $a_w$ values of 0.4 to 0.6. High moisture content of 18 per cent resulted in microbial growth (Slade and Levine, 1991), non enzymatic browning and caking. In Hungarian paprika, moisture content should be adjusted to about 10 per cent which is considered optimum during grinding (Dimitrov *et al*., 1969). The Spanish paprika should have a moisture of 10-12 per cent to have greater colour (Salmeron and Garrido, 1976) whereas American paprikas were dried to a moisture content of 6 per cent for grinding and then rehydrated to 12 per cent for better colour retention during storage (Feinberg, 1973). Studies by Osuna-Garcia and Wall (1998) showed that colour loss in ground paprika can be minimized by 50 per cent during storage at ambient temperature and humidity by increasing the pre-storage moisture content to 15 per cent. Sorption isotherm studies of Naik *et al*. (2001) indicated that moisture content of 9.6 per cent [equilibrium relative humidity (ERH) 57%] is quite safe for storage of Byadgi chilli at ambient condition, whereas a moisture level of more than 11.2 per cent induced mold growth.A moisture content of 10 to 11 per cent with subsequent storage at -16$^0$ C was shown to be the best with minimum colour loss in ground capsicum (Guzman *et al*., 1973; Malchev *et al*., 1982).

**Oleoresins :**

Chilli oleoresin is obtained by the extraction of chillies with approved food grade solvent and subsequent careful removal of the solvent by distillation while retaining the functional components in the total extract. Three types of capsicum oleoresins are made to serve different end uses (Govindarajan, 1985b) *viz.,* oleoresin paprika, oleoresin red pepper and oleoresin capsicum (African). Oleoresin paprika is essentially used as a food colourant; oleoresin red pepper is a source of both colour and pungency; while, oleoresin capsicum (African) is the most pungent principle used for the counter irritant properties in plasters and some pharmaceutical preparations(Govindarajan, 1985a). The oleoresins from different varieties of whole chillies contain 1-3 per cent capsaicinoids and those from very high pungency groups like small African chillies 4-6 per cent capsaicinoids. Chilli and paprika oleoresin have the advantage of hygiene and concentration leading to cost advantages of freight, storage space, economy and stability. In the long run, use of oleoresins even proves economical, besides convenient, since the concentrated forms save on transport and storage over the bulky inventory of powdered spices (Govindarajan, 1985b).

**Colour :**

The colour of chillies is due to the blend of various pigments of which, keto-carotenoids, capsanthin and capsorubin constitute 70 to 80 per cent of the total carotenoids and contribute to the unique red colour. The total carotenoid content in *Capsicum annuum* varies from 2,950 to 16,600 µg $g^{-1}$ dry weights (Levy *et al*., 1995). Preservation of the attractive red colour of chillies during storage has been a major problem (Krishnamurthy and Natarajan, 1973) because of the time lag for the product to reach the consumer (Philip *et al*., 1971) and pigment content of the dehydrated pods (Locey and Guzinski, 2000).Carotenoid loss or destruction has been recognized as one of the two major causes for colour changes in dried red pepper products (Ramakrishnan and Francis, 1973). Red xanthophylls are very susceptible to the oxidative degradation process such as lipoxygenase catalyzed linoleic acid oxidation (Biacs *et al*., 1989). Oxidative degradation of carotenoids caused by exposure to heat, light and oxygen is an important factor which affects paprika colour loss during storage (Biacs *et al*., 1994).

**Factors affecting colour degradation rate are indicated below:**

***Moisture content* :**

Salwin (1959) pointed out that water protects pepper particles against attack by oxygen by providing a protective film in the form of a monomolecular layer. Natarajan *et al*. (1969) studied the storage behaviour of whole chillies stored in sealed cans over a period of 6 months and observed that the samples with moisture content of 11.0 to 12.9 per cent gave higher colour values (expressed as b-carotene) compared to samples stored with moisture content below 9.0 per cent. Whereas, samples with moisture content below 7.0 per cent turned pale. The spectral curves of the colour extract of blackened samples stored at higher moisture content showed a shift in the absorption maxima and there was an increase in carbonyl compounds, indicating the possibility of non-enzymatic type of browning reaction.

**Temperature :**

Storage at higher temperature increased the rate of colour destruction and resulted in blackening of whole chillies. This deterioration of colour was also ascribed to non-enzymatic browning, accentuated by both the moisture and ambient temperature. (Krishnamurthy and Natarajan,1973) and Phillip *et al.* (1971) gave a scheme of oxidation of capsanthin by oxygen, wherein the hydroxyl groups of capsanthanin were oxidized. Carotenoid degradation in paprika has been explained as an auto oxidative process (Chen and Gutmanis, 1968; Chou and Breene, 1972) but such autooxidation may be coupled with enzymatic activity (Kanner *et al.*, 1977; Biacs *et al.*, 1992). Refrigerated storage at 5°C slowed down the deterioration of colour. Storage temperature was found to have greater effect on the colour stability of the pepper than did light, the kind of container or whether the pepper was stored as whole or ground (Lease and Lease, 1956). While, the beneficial effects of frozen and chilled storage were demonstrated quantitatively on colour retention by dried paprika by Guzman *et al.* (1973) and Gimenez *et al.* (1984). Malchav *et al.* (1982) showed that the colour stability in paprika was strongly dependent on the temperature of the air used in drying of the product: the higher the drying temperature, the lesser the stability of pigments during storage. Lowering storage temperature and reducing the package free space volume improved carotenoid retention (Lee *et al.*, 1992) as refrigeration temperatures reduce free radical formation (Biacs *et al.*, 1992) .

**Light :**

Although the carotenoids are sensitive to light, this sensitivity is dependent on the presence of oxygen, the light usually being a catalyst to induce oxidation. In the complete absence of air, light has little effect (Bunnell and Bauernfeind, 1962). Van Blaricom and Martin (1951) reported that chillies stored in the dark retain their colour much longer than those stored in the light. Mar-Rosalita and Francis (1969) found out that bleaching of paprika powder by sunlight resulted in loss of nearly 96 per cent of the total colour expressed as b-carotene. Clean glass container were superior to opaque polyethylene bags in regard to colour retention of paprika as glass prevents the entry of oxygen (Stringheta *et al.*, 1979).

**Storage time :**

Morais *et al.* (2001) reported that the overall decomposition rate of pigment was dependent on the storage time and on the presence of light and oxygen, the effect of storage time being the most decisive factor, while the impact of oxygen was the lowest.

**Biochemical parameters :**

*Capsaicinoids, Capsaicin, Afaltoxin and Scoville Heat Unit*:

Pungency of capsicum is due to the accumulation of capsaicin (N-[4-hydroxy – 3- methoxy – phenyl methyl ) – 8 – methyl – 6 – nonenamide) and other pungency principles which include dihydro capsaicin (N–[(4-hydroxy–3–methyoxyphenyl)–methyl]–8 methylnonenamide) and to a lesser extent, norcapsaicin (n-[(4-hydroxy–3–methoxy phenyl) methyl]–7–methyl–5-octenamide), nordihydrocapsaicin (N-(4-hydroxy–3-3 methoxy phenyl) methyl]–7– methyloctanamide), homocapsaicin (N- [(4-hydroxy – 3 methyoxyphenyl) – methyl] –9–methyl–7–decenamide) and homodihydrocapsaicin (N-[(4-hydroxyl–3 methyoxyphenyl) methyl]–9–methyl decanamide). Additional related capsaicinoids have also been identified as trace constituents of capsicum (Jurenitsch *et al.*, 1979).

In fruits, capsaicin is synthesized in the placenta (Iwai *et al.*, 1979; Fujiwake *et al.*, 1982). It stimulates the action of the muscles of the stomach and intestine and thus, improves digestion. This makes chillies an attractive condiment (Andrews, 1984). Besides the use of capsaicin as an additive, it is used in clinical trials, including the use of capsaicin cream in dermatological therapy to prevent chronic pain associated with post-herpetic neuralgia, and neuropathy (Palevitch and Craker, 1995) and peripheral painful conditions like rheumatoid and arthritis (Surh and Lee, 1996). Wilbur Scoville in 1912 developed a scale to measure the “heat levels” of chilli peppers. In the original Scoville test, a panel of volunteers would be asked to determine the dilution of the chilli pepper solution that no longer can cause burning discomfort in the mouth (Borges, 2001). The hottest chilli pepper recorded was Habanero with a Scoville pungency of 577,000 in contrast to the sweet Italian bell pepper with a pungency of 0 units (Bellringer, 2001). Indian scientists have recently claimed that Tezpur chilli grown in the north east has the highest Scoville units of 8,55,000 (Anonymous, 2000c). In *Capsicum annuum*, the ratio of capsicum to dihydrocapsaicin varies from 1.36 – 1.71 (Estrada *et al.*, 1997), while Boronat *et al.* (1999) have reported a ratio of 0.64 to 1.94.

Capsaicinoid accumulation is controlled by several factors *viz.*, age of the plant, temperature, light and nutritional status (Iwai *et al.*, 1979). Govindarajan (1985a) has reported that cultivar is the most important factor that determines the amount of capsaicinoid and the value of capsaicinoids vary from less than 0.1 per cent to over 1 per cent. Dabrowska *et al.* (2000) have also reported that the capsaicin content depends on the genotype. Van Blaricom and Martin (1951) reported that the factors responsible for pungency are not correlated with colour retention. They also opined that capsaicin was retained for longer periods and was present even in chilli which had lost their original colour. Govindarajan (1985a) was also of the opinion that during prolonged storage, unlike the marked deterioration in colour, little effect was recorded on pungency. Kim *et al.* (2002) also reported that capsaicinoids in red pepper were not related to colour stability.

**Aflatoxins :**

Aflatoxins are toxic metabolites elaborated by *Aspergillus flavus* and *A. parasiticus*. These toxins are highly carcinogenic and elicit a wide spectrum of toxic effects when foods and feeds contaminated with aflatoxins are ingested (Peskta and Bonday, 1990). Among 18 different types of aflatoxins identified, major members of aflatoxins are $B_1$, $B_2$; $G_1$, $G_2$. *A. flavus* typically produces Aflatoxin $B_1$ (AFB1) and Aflatoxin $B_2$ (AFB2), whereas *A. parasiticus* produces AFG1, AFG2 as well as AFB1 and AFB2. The potency of toxicity, carcinogenicity and mutagenicity is in the order of AFB1> AFG1> AFB2> AFG2. Aflatoxins fluoresce strongly in ultraviolet light (365 nm); $B_1$ and $B_2$ produce a blue fluorescence; whereas, G1 and G2 produce green fluorescence (Reddy and Waliyar, 2005).

**Influence of moisture on aflatoxins :**

Moisture is the primary factor which controls mold growth (Scott and Kennedy, 1973).A water activity ($a_w$) of 0.84 was considered by Hunter (1969) to be the critical lower range for growth and aflatoxin production by *A. flavus* and $a_w$ of 0.86 as the critical level for its fast growth. Holmquist *et al.* (1983) reported that the maximum growth of the fungus occurred when the $a_w$ was highest (0.99) and as the $a_w$ of the medium decreased, the amount of growth also decreased. When the $a_w$ was 0.80, no fungal growth was observed. Water activity also has a role to play in the inhibition of growth or the length of time before the growth became visible. At $a_w$ of 0.85, growth of both *A. flavus* and *A. parasiticus* was not seen until the fourth day. When the $a_w$ was 0.90, growth became evident even after the second day and at higher levels of $a_w$, growth became evident within 24 h.The limiting water activity for the development of *A. flavus* is 0.80 (Northolt and Bullerman, 1982) and for toxin production it is 0.83 to 0.87 (Weidenborner, 2001).Results by Debevere (2005) have shown that to obtain a microbiological stable product, a water activity of maximum 0.60 is required and this corresponds to a water content of approximately 14 per cent. More specifically, to prevent the growth of *A. flavus*, a water activity of maximum 0.83 is required which corresponds with a water content of approximately 20 per cent.

**Influence of temperature on aflatoxins :**

Diener and Davis (1967) and Ayerst (1969) reported the maximum and minimal temperature for the growth of *A. flavus* as 43$^0$C and 12$^0$ C. The optimal growth of *A. flavus* occurs over a temperature range of 29-35$^0$ C when other growth conditions are favourable (Trenk and Hartman, 1970).

**Microbiological parameter :**

Studies on the effect of modified atmospheric packaging in chiku by Mohamed *et al.* (1996) have shown that minimum spoilage due to pathogens was seen in the vacuum packed fruits and no pathogenic spoilage was observed at storage temperature of 5$^0$C. Sanjeev and Ramesh (2006) have reviewed that though vacuum packaging can be used to extend the shelf life and keeping quality of food, aerobic spoilage can still occur in such packaged products depending on the level of residual oxygen in the package headspace. The level of residual oxygen depends on factors such as the oxygen permeability of the packaging material, the ability of food to trap air, leakage of air through poor sealing and inadequate evacuation.

**Effects of vacuum packaging on quality of other agricultural produce :**

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. The reduction of the oxygen content of these packs was found to delay the onset of fat rancidity (Anonymous, 1977a). Vacuum packaging of cocoa beans at 7.3 per cent moisture content for one year also has produced good results with the vacuum seen to destroy the insect larvae (Anonymous, 1977b).Vacuum packaging of unblanched frozen vegetables had a favourable effect, resulting in a longer shelf life of the produce. 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 (Steinbuch, 1980).Balasubramanyam *et al.* (1983) observed that for roasted and salted, spiced peanuts, a shelf life of 180 days under standard Indian conditions (65% RH, 27$^0$ C) could be attained only in vacuum packed, polyester/ polyfoil/polylaminate pouches as against a shelf life of barely 25 days in polyolefin and cellophane packages packed without vacuum. Sheikh *et al.* (1985) reported that 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.

Storage trials conducted on shelled groundnut seeds by Rouziere (1986) revealed that no changes in physico-chemical properties occurred during high vacuum storage at any temperature or in technological quality of peanuts during nitrogen compensated vacuum storage at ambient temperature, over a period of 18 months. Beirne and Alison (1987) reported that enzymatic discolouration in potato strips could be reduced considerably by vacuum packaging with dipping in ascorbic acid based antioxidant solutions and storing at 5$^0$C. 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. Dull and Kays (1988) found that vacuum packaging maintained colour and greatly reduced mechanical damage in pecan kernels [*Carya illinoensis* (Koch).Wang] for up to 6 months of storage, at 24$^0$C and 60 per cent RH.

Paakkonen *et al.* (1989) reported that at room temperature, the intensity of odour and taste of freeze dried dill (*Anethum graveolens* L.) was better preserved in vacuum packages than in glass jars or paper bags, for up to 12 months of storage.

Gorris and Peppelenbos (1992) described that vacuum packaging of fresh produce can extend their shelf life and prevent enzymatic browning of cut fruits and vegetables too. It was found that vacuum packing of green unripe banana could prolong the shelf life of banana to more than 40 days. A similar study by Pandiarajan *et al.* (1994) on green Rasthali bunches of banana revealed that bunches could be stored in a vacuum pack at room temperature for up to 3 weeks. The fruits remained hard and green at the end of storage period.Severini *et al.* (2003) concluded that vacuum conditions were necessary for the successful preservation of roasted almonds, but the effectiveness of the vacuum was apparent only when combined with a good oxygen barrier provided by the selected packaging film. Ada *et al.* (2003) studied the physical qualities of minimally processed potatoes (Desiree variety) stored for 7 days under vacuum packaging. It was reported that the main quality parameters were constant during storage and the shelf life of potatoes could be effectively extended to nearly one week under refrigerated storage by using vacuum packaging systems. Sharma *et al.*(2006) monitored the quality changes of deep fat fried cashew kernels under vacuum packaging with respect to chemical parameters like peroxide value, free fatty acid content, thiobarbituric acid value, total carbonyls and fatty acid profile. 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.

**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. In this direction, the present study would highlight the importance of vacuum packaging for maintaining the viability, vigour and quality of seeds for long term storage. The study will also help us in understanding the physiological and biochemical changes during the storage period. The outcome of the study is expected to benefit the farmers, seed producers, traders and exporters for maintaining the quality of the seed. Vacuum packaging could be useful to farmers from the point of preserving the viability of seeds. Future studies may undertake germination, vigour and viability tests on chilli seeds to study the same. This technology has huge potential and therefore, it needs to be explored for different dehydrated products, food grains and other dry spices and food products, so that post harvest losses can be minimized to a great extent and food hygiene can be maintained.

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