

# **INFLUENCE OF VACUUM PACKAGING AND LONG TERMS STORAGE ON QUALITY IN CHILLI POWDER**

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# 1. INTRODUCTION

Spices sector is one of the most vibrant sectors of the Indian agricultural trade. The history of Indian spices dates back to the beginning of the human civilization. There are references about Indian spices and their uses in the Vedas (6000 BC), by the Babylonians and Assyrians (around 3000 BC) and in the Old Testament (1000 BC) of the Bible. Spices were the inducement for war, voyages, expeditions and in shaping the course of world events and history. And today, India is the largest producer, consumer and exporter of spices in the world market. According to the world spices production statistics 2003-2004 by FAO, India produces 86 per cent of the spices by volume; contribute around 6 per cent by volume in total agriculture export of India and 25–30 per cent by value in the global spice market (Anon., 2006a).

Chilli (*Capsicum annuum* L.), an important member of Solanaceae family, is an indispensable spice cum condiment in Indian cuisine. It was discovered by Christopher Columbus when he landed in South America and India got the first taste of this pungent spice by the Portuguese explorer Vasco-da-Gama in 1498.

Chilli is popularly known as capsicum, red pepper or paprika depending upon the species. They are used fresh and processed, dried whole, frozen and canned and as value added products like powder, oleoresin, capsanthin, chilli paste and chilli oil which are in vogue in the present global market.

India is the world's largest producer and exporter of chilli. Among the spices cultivated in India, chilli has the highest domestic per capita consumption and ranks first in area (8.83 lakh ha) with a productivity of 1266 kg/ha. Andhra Pradesh followed by Karnataka is the major chilli growing states in India. During 2004-05, chilli had fetched the highest export earnings of Rs.499 crores (Anon., 2006a) and has thus attained the status of high value crop in the country in recent years.

Chilli, besides imparting pungency and red colour to the dishes, is a rich source of Vitamin A, B, C and E and minerals like Ca, P, Fe, Na and Cu in trace amounts. The pungency in chillies is due to an alkaloid capsaicin which has high medicinal value. Capsaicin is an amide derivative of vanillylamine and 8 methyl-non-trans-6-enoic acid (Maria *et al.*, 1993). The principal colouring pigment is derived from carotenoid capsanthin and capsorubrin, together with cryptoxanthin and zeaxanthin as fatty acid esters (Zechmeister and Cholnoky, 1934).

Till a decade back, India was exporting spices in raw form and in bulk, mainly as bulk packing. The trend has now been changed and export of spices in value added forms has presently a share of about 30 per cent of the total export of spices from India, which was only 5 per cent a decade ago (Potty and Krishna Kumar, 2000). The use of whole spices in food processing is also limited, as they do not lend their full characteristic flavour, colour or pungency, but only provide pleasing appearance. Hence, spices are ground to release the natural flavour and for easy dispersion in curries (Anon., 1964). Today, powdered spices, masala mixes (mixture of different ground spices) and curry powder are more in demand in the market.

Ground (powdered) paprika is the product obtained by grinding the ripe fruits of various varieties of paprika (*Capsicum annuum* varieties longum, grossum, abbreviatum, typicum, etc). It is prepared from the pericarp and the seeds of the paprika fruit; in addition, it may contain a variable proportion of other parts of the fruit, such as the placenta, the calyx and the stalk, but this proportion should not be greater than that of the fruit itself. The colour of ground (powdered) paprika varies according to the quality from vivid brilliant red through yellow and brownish red to pale reddish brown (Anon., 1984).

Chilli powder is extensively used for food flavouring and colouring meat foods, snack foods and sauces. Chilli powder has many beneficial properties, making it an important part in ayurvedic medicines to fight many diseases, destroy harmful toxins and stimulate gastric juices that help in digesting food. It also helps in clearing nasal congestion, relieves throat infection and acts as pain killer in muscle spasm.

In the developed importing countries, with their diverse requirements, chillies are largely used in the value added powdered form in different combinations of pungency, colour and particle size as specialty products. Standardized blends of specific varieties of chillies in the ground form, which cover a wide range of pungency and colour, have been successfully marketed in the US as ready-to-use seasonings for different type of foods. Some popular blends include cayenne pepper, red pepper, crushed red pepper, chilli powder, barbecue seasonings and curry powder (Govindarajan, 1985b).

The market for ground chillies of the mild to medium pungency varieties in West European markets appear promising as seen by increasing imports in this form from China, Pakistan and India to Federal Republic of Germany, France, UK & Japan. In the West, there is growing reluctance to grind chillies due to its persistent irritant property and high cost of grinding. The developing countries growing chillies like India with a large variety combining various levels of pungency and colour, can take advantage of these situations, only if they assure compliance to the stringent standards of the Western countries (Govindarajan, 1985b).

Quality deterioration in spices and spice products pose a major threat during storage as they are hygroscopic in nature and highly sensitive to moisture. Absorption of moisture may result in caking, discolouration, hydrolytic rancidity, mold growth and insect attack. Carcinogenic metabolites, aflatoxins, elaborated from *Aspergillus flavus* and *A. parasiticus* are a major problem encountered in stored spices. Oxidation of the carotenoids during drying and storage accounts for the colour loss in the product and thus quality deterioration. Furthermore, the absorption of foreign odours as a result of inefficient packaging may also be a serious problem in ground spices.

The relative high cost of ground chilli and the overwhelming importance of retaining their aromatic and special flavour component and qualities justify the selection of proper packaging strategy. With this background, the present study was undertaken to open up a new methodology of packaging of chilli powder with the following objectives:

1. To study the changes in quality parameters under vacuum packaging of chilli powder over a period of time.
2. To assign specific reasons for maintaining quality or deterioration, if any, under vacuum packaging in chilli powder.

## 2. REVIEW OF LITERATURE

The global spice industry is poised for a major leap in the 21<sup>st</sup> century with the global trade in spices expected to attain even higher levels due to the anticipated advances in food industry. In this scenario, chilli is acclaimed as one of the most sought after spices as there is a rapid shift from synthetic substances to natural plant products in the food, pharmaceutical and cosmetic industry in the world over. Of all the great concerns to the spices industry in WTO era, it is imperative that Indian farmers should become competitive in the international market through quality consciousness.

Packaging of food stuffs is an integral part of the techniques used to extend the shelf life of food products and to maintain quality. Elimination of oxygen from the pack by vacuum packaging is a technique that can be adopted to prevent food spoilage by oxidation. Studies pertaining to vacuum packaging and its influence on quality of chilli powder are very meagre. Hence, the related aspects are reviewed and presented in this chapter.

### 2.1 EXPORT SCENARIO OF CHILLI POWDER

India has emerged today as the foremost producer and exporter of chillies contributing to almost one-fourth of the world production. But due to the high domestic consumption and low international demand for our chillies in the developed countries such as North America and European countries, India exports only 5 to 8 per cent of its output (Bhullar *et al.*, 2005).

It is estimated that around 25-30 per cent of chilli is used for powder preparation (Anon., 2006b). India exported 25,000 tonnes of chilli powder, 40,000 tonnes of whole chillies, 1,000 tonnes of oleoresins of paprika and 285 kg of oleoresins of chilli at the gross value of Rs. 346.2 crores in 2001-02. USA was the major importer of chilli powder with 8,400 tonnes of imports followed by UAE (6470 t) and UK (1700 t). Other importers include Russia, Saudi Arabia, The Netherlands, Egypt, Italy, Mexico, Ukraine, Sri Lanka and Singapore with imports ranging between 300-400 tonnes (Bhullar *et al.*, 2005).

Export statistics of chilli powder indicated a highly fluctuating trend with the exports of Rs. 65.08 crores in 2001-02 (Bhullar *et al.*, 2005), a sharp rise in 2002-03 (Rs.113.14 crores) and a decline (Rs.105.56) in 2003-04 (Gandhi, 2006).

#### 2.1.1 Concerns for export

Food Standard Agency (FSA), United Kingdom ordered a recall of 575 products in which red chilli powder was alleged to be contaminated with Sudan dye, which was used as an ingredient (Anon., 2005). To take care of such incidents, the Spices Board announced two important changes to the norms applicable for export of chillies and chilli product which stipulated a certificate to be obtained from the Spices Board indicating that the consignment is free from Sudan I to IV and does not contain aflatoxin beyond acceptable limits. This rule has taken effect in respect of export to the EU, the US, West Asia and other destinations (Gandhi, 2006).

The future scope for increasing area and production of chillies depends upon its export, as the world consumption of chillies and paprika is going up due to increasing popularity of ethnic foods. India stands a good chance in exporting chillies, but what is required is the production of quality chillies, which have demand in the international market.

### 2.2 QUALITY REQUIREMENTS FOR EXPORT

Pre-requisite to tap the potential of price competitiveness is to meet the quality standards and other import regulations of the importing countries (Bhullar *et al.*, 2005). Different countries have set different limits for various parameters to qualify the export standards, the details of which are given below.

## 2.2.1 Export standards for USA

### 2.2.1.1 Physical parameters

Spices exported to USA should conform to the cleanliness specifications stipulated by the American Spice Trade Association (ASTA) and also the Defect Action Levels (DAL) enforced by the Food and Drug Association (FDA) (Jacob, 2000).

- i) Whole insect dead by count - 04
- ii) Excreta mammalian (mg/lb) - 1.0
- iii) Other excreta (mg/lb) - 8.0
- iv) Mold (% by wt.) - 3.00
- v) Insect defiled / infested (% by wt.) - 2.50
- vi) Extraneous foreign matter (% by wt.) - 0.50

(Jacob, 1998)

Defect Action Levels prescribed by USFDA for ground paprika

Defect	Defect Action Level
Mold	Average mold count is more than 20%
Rodent filth	Average of more than 11 rodent hairs / 25 g
Insect filth	Average of more than 75 insect fragments/ 25 g

(Sivadasan, 1995)

### 2.2.1.2 Microbiological parameters

Though ASTA has not so far specified the tolerance limits for microbiological parameters, the limits suggested by International Commission on Microbiological Specification for foods are widely accepted. Accordingly, the maximum level of total plate count (TPC) tolerated is  $1.0 \times 10^6$  cfu/g. The yeast and mold should have count below  $1.0 \times 10^4$  cfu/g (Nair, 1998).

## 2.2.2 Export standards for Europe

The spice industry in Europe thrives mainly on the trade in ground spices which are used mainly as food ingredients and hence all the horizontal regulations concerning food processing and sale are of direct relevance to spices. Presently, the European Spice Association (ESA) in collaboration with the Spice Trade Association of various European countries is attempting to lay down uniform standards and code of practice for the whole of Europe, in line with the EC Food Hygiene Direction (93/43/EEC) (Nair, 1998). Many EEC (European Economic Commission) countries have prescribed tolerance levels for aflatoxin. German specification for aflatoxin B<sub>1</sub> and B<sub>1</sub> + B<sub>2</sub>+ G<sub>2</sub> are 2 and 4 ppb respectively. Other European countries have prescribed the limits for aflatoxin B<sub>1</sub> which varies from 1 to 10 ppb (Jacob, 1998).

### Requirements of spices according to honest trading practices in Germany

Type of spice	Minimum oil content (%)	Ash (%)	Maximum sand content (part of ash not soluble in hydrochloric acid) (%)
Paprika powder (sweet)	0.1	6.5	1
Paprika powder (hot)	0.05	7.5	1
Alcohol extract	Aprox. 25%		

(Nair, 1995)

### Dutch regulations regarding cleanliness specifications

Name of spice	Ash content maximum (%)	Sand content (AIS) Max. (%)	Volatile oil minimum (%)
Paprika powder	10.0	1.0	-

(Nair, 1995)

### ESA specifications on spices

Off odours	Shall be free from off odour or taste
Infestation	Should be free in practical from live and / or dead insects, insect fragments and rodent contamination visible to the naked eye
Aflatoxin	Maximum limit for total aflatoxin is 20 ppb

### ESA specifications on paprika powder

	Ash (% w/w) max.	Acid insoluble Ash (% w/w)	H <sub>2</sub> O (% w/w) max.	Volatile oil (% v/w) min.
Paprika powder	10	2	11	-

(Nair, 1998)

## 2.2.3 The International Organization for Standardization (ISO)

ISO is a worldwide federation of national standards institute (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. ISO describes ground chillies as the product obtained by grinding whole chillies without any added matter. These products take the form of a powder of widely varying colour, from deep-red through orange-yellow to pale green. For the needs of international trade, the powder may be ground to any required particle size, according to the agreement between the parties concerned. In general, the maximum particle size is 500 µm (Anon., 1997a).

### 2.2.3.1 Odour and flavour

Ground chillies and capsicums shall have a characteristic strong odour with an acrid note, causing nasal irritation. The flavour shall be characteristic of chillies, producing a strong acrid burning sensation which is very persistent.

### 2.2.3.2 Freedom from insects and molds

Ground chillies and capsicums shall be free from live insects and molds, and practically free from dead insects, insect fragments and rodent contamination visible to the naked eye.

### 2.2.3.3 Extraneous matter

Extraneous matter includes all matter present in the sample which is not from chillies or capsicums of the variety under consideration and all other foreign matter and, in particular, stalks, leaves, soil and sand. The proportion of extraneous matter shall not exceed 1 % (m/m).

### 2.2.3.4 Chemical requirements

Ground chillies and capsicums shall comply with the requirements given in the table below (Anon., 1997a):

Characteristic	Requirement
Max. moisture content (% m/m)	11
Max. total ash (% m/m) on dry wt. basis	10
Max. acid-insoluble ash (% m/m) on dry wt. basis	1.6

## 2.2.4 Indian Standard specifications

The Indian Standard specifications for chilli powder are indicated below (Anon.,1995).

Characteristic	Value
Moisture (%) max.	10.0
Total ash (%) max.	8.0
Acid insoluble ash (%) max.	1.5
Crude fiber (%) max.	30.0
Ether extract, nonvolatile (%) min.	12.0
Fineness, % of ground product to pass through	100 through 500 $\mu$ sieve

## 2.3 PACKAGING

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 (Doughas *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 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 (Ranganna, 1986).

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 (Ranganna, 1986).

## 2.4 VACUUM PACKAGING

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).

### 2.4.1 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

### 2.4.2 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.

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 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). Oxygen sensitive foods should thus be stored in packages with initial contents of head space oxygen below 2% to ensure long shelf life (Rooney, 1983). 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% residual oxygen and 97.929 kPa 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 kPa is required (Eselgroth, 1951). 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).

### 2.4.3 Influence of vacuum packaging on quality

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% 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 (Anon., 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°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 discolourations in potato strips by combining vacuum packaging with dipping in ascorbic acid based antioxidant solutions and storing at 5°C. They reported that vacuum packaged strips retained excellent colour for atleast 14 days either without antioxidant or with 1% or 5% ascorbic acid compared to control. After 14 days of storage, strips dipped in 1% 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.

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.

Anon. (2000b) 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°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°C, the application of partial vacuum packaging increased shelf life from 3.8 to 9 months compared to simple sealing.

## 2.5 QUALITY PARAMETERS

### 2.5.1 Moisture content

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 (Doughas *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 & 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% resulted in microbial growth (Slade and Levine, 1991, Lee *et al.*, 1992), non enzymatic browning and caking (Kanner *et al.*, 1977, Lee *et al.*, 1991).

In Hungarian paprika, moisture content should be adjusted to about 10% which is considered optimum during grinding (Dimitrov *et al.*, 1969). The Spanish paprika should have a moisture of 10-12% to have greater colour (Salmeron and Garrido, 1976) whereas American paprikas were dried to a moisture content of 6% for grinding and then rehydrated to 12% 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° C was shown to be the best with minimum colour loss in ground capsicum (Guzman *et al.*, 1973; Malchev *et al.*, 1982).

### 2.5.2 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.

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).

### 2.5.3 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  $\mu\text{g g}^{-1}$  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, 1979). 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.

#### 2.5.3.1 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% gave higher colour values (expressed as  $\beta$ -carotene) compared to samples stored with moisture content below 9.0 per cent. Whereas, samples with moisture content below 7.0% 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.

#### 2.5.3.2 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). Phillip *et al.* (1971) gave a scheme of oxidation of capsanthin by oxygen, wherein the hydroxyl groups of capsanthin 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).

#### 2.5.3.3 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  $\beta$ -

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).

#### 2.5.3.4 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.

### 2.5.4 Capsaicinoids 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 – methoxyphenyl) – 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 – methyl – 7 – methyloctenamide), homocapsaicin (N- [(4-hydroxy – 3 methoxyphenyl) – methyl] – 9 – methyl – 7 – decenamide) and homodihydrocapsaicin (N-[(4-hydroxyl – 3 methoxyphenyl) methyl] – 9 – methyl decenamide). 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 (Anon., 2000c). In *Capsicum annum*, 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.

### 2.5.5 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 (Peshta and Bonday, 1990). Among 18 different types of aflatoxins identified, major members of aflatoxins are B<sub>1</sub>, B<sub>2</sub>; G<sub>1</sub>, G<sub>2</sub>. *A. flavus* typically produces Aflatoxin B<sub>1</sub> (AFB<sub>1</sub>) and Aflatoxin B<sub>2</sub> (AFB<sub>2</sub>), whereas *A. parasiticus* produces AFG<sub>1</sub>, AFG<sub>2</sub> as well as AFB<sub>1</sub> and AFB<sub>2</sub>. The potency of toxicity, carcinogenicity and mutagenicity is in the order of AFB<sub>1</sub> > AFG<sub>1</sub> > AFB<sub>2</sub> > AFG<sub>2</sub>. Aflatoxins fluoresce strongly in ultraviolet light (365 nm); B<sub>1</sub> and B<sub>2</sub> produce a blue fluorescence; whereas, G<sub>1</sub> and G<sub>2</sub> produce green fluorescence (Reddy and Waliyar, 2005).

### 2.5.5.1 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.

### 2.5.5.2 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°C and 12 °C. The optimal growth of *A. flavus* occurs over a temperature range of 29-35 °C when other growth conditions are favourable (Trenk and Hartman, 1970).

## 2.6 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 °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.

### 3. MATERIAL AND METHODS

Opening up of the economies through globalization and liberalization, has led to the free flow of commodities across countries. In this scenario, quality has become an important criteria as the consumers world over are becoming more conscious of the quality. Therefore, there is a need to ensure the quality to meet the stringent quality requirements of the importing countries. There is also a need for proper long term storage of spice products like chilli powder to avoid gluts in the market during years of uneven production. Hence, influence of long term storage on quality was studied in vacuum packed chilli powder. The details regarding the experimental material and quality parameters analyzed are described in this chapter.

#### 3.1 EXPERIMENTAL MATERIAL

Chilli fields in and around Dharwad and Haveri districts were thoroughly surveyed, and after visiting nearly 50 farmers, a field of Mr. Basanagouda D. Naganagoudar having uniform crop stand, vigour and growth of chilli was selected from Haliyal village in Dharwad district for procuring the experimental material. Before the harvest of the crop, the farmer was instructed regarding the right stage of harvest, the precautions to be followed in transporting the produce from the field to the drying yard and the method of drying.

Precautions were exercised not to contaminate chilli during drying with the soil surface so as to contain the infection from microflora particularly *Aspergillus flavus*, which is one of the most important criteria for export purpose.

For the experiment, Byadgi Kaddi variety was procured from the farmer. This variety is red in colour with less pungency and has properties similar to paprika, which has high demand in the spice market. The fruits were dried to approximately 8 per cent moisture and then ground in a special spice mill to a fine powder of 500  $\mu$  mesh size. The moisture content of chilli powder at the time of imposing packaging treatments was 8 per cent. The powder was vacuum packed in 2 kg bags; while the control, in 9 kg high density polyethylene (HDPE) bags. The packaging material used was a multi layered laminate with barrier properties for oxygen, carbon dioxide, water vapour and UV light. It also had one layer of polypropylene for tensile strength. Both vacuum packed and HDPE bags were stored under different conditions as mentioned below.

##### I. Moisture level - One

- i) 8%

##### II. Storage conditions / temperature - Three

- i) Room temperature, Light ( $25\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ )
- ii) Room temperature, Dark ( $25\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ )
- iii) Cold storage ( $4\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ )

##### III. Packaging material – Two

- i) Vacuum packaging
- ii) HDPE bags

With the above, the experiment consisted of the following treatment combinations (Plate 1a, 1b).

- T<sub>1</sub> = Vacuum packed bags stored at room temperature under light (VC, RT, light)  
T<sub>2</sub> = Vacuum packed bags stored at room temperature under dark (VC, RT, dark)  
T<sub>3</sub> = Vacuum packed bags kept under cold storage (VC, CS)  
T<sub>4</sub> = HDPE bags stored at room temperature (HDPE, RT)  
T<sub>5</sub> = HDPE bags kept under cold storage (HDPE, CS)



Plate 1a. Packaging and storage treatments (T1-T3)



**T<sub>4</sub> : HDPE bags stored at room temperature (HDPE, RT)**



**T<sub>5</sub> : HDPE bags kept under cold storage (HDPE, CS)**

**Plate 1b. Packaging and storage treatments (T<sub>4</sub> and T<sub>5</sub>)**

**Replications : Four**

**Design : Completely Randomized Design**

The temperature in the cold storage was around  $4^{\circ}\text{C} \pm 1^{\circ}\text{C}$ . For the light treatment, the bags were stored in the laboratory with normal diffused light as existed without any additional lighting. For dark treatment, the racks were covered with thick black cloth to protect the infiltration of even diffused light. Both the vacuum packed bags and HDPE bags were stored properly in the iron racks without stacking such that all the bags were uniformly exposed to the particular treatment condition.

## **3.2 VACUUM PACKAGING OF CHILLI POWDER**

The machine used for vacuum packaging of chilli powder was OLPACK 501/V manufactured by INTERPRISE – BRUSSELS S.A., BRUXTAINER DIVISION, Belgium (Plate 2). The general description of the machine and the details regarding the setting up of machine, its operation and the procedure involved in vacuum packaging are described herein.

### **3.2.1 General description of vacuum packaging machine**

The OLPACK machine is a vertical vacuum packaging system designed and developed for vacuum packing solid, liquid and semi-liquid food stuffs. The bags are filled with the product by means of a “bag shaping” guide to be thus manually placed inside the machine, which creates vacuum by means of a special pump. The bag is thus sealed by means of a thermal sealing system, featuring a sealing bar for double sealing. During the cycle, it is possible to inject inert gas inside the bag, by means of special gas nozzles. The entire packing and thermal sealing cycle is controlled by two independent control software systems with the relative control panels. The machine is basically composed of the following.

- Frame
- Vacuum chamber bell
- Cycle controls
- Heat regulator for the pulse type sealing system
- Vacuum pump
- Heated sealing bar
- Compressed air system
- Bag stretching bar
- Red mushroom on a yellow background
- 2-position power switch
- Red indicator light

The machine can also accommodate some additional components, viz.,

- Infeed roller way
- Roller way with guides inside the vacuum chamber bell
- Different types of bag shapers
- Different types of bag stretching bars



Plate 2. Bruxtainer vacuum packaging machine with the mould used for vacuum packaging

### **3.2.2 Setting up of the machine**

- The leveler was kept on top of the machine, whenever it was found to be unlevelled, the leg of the machine was turned with the help of spanner bolt until the machine was leveled. The conveyor of the leg of the machine was also leveled, by keeping the leveler on a flat surface on top of the conveyor. Similarly, the conveyor outside the machine and the sealing bar was also leveled.
- The air tube (blue colour) was connected to the machine at a vent marked "AIR".
- The compressor was switched on and the corresponding readings on the gauge (black) hanging on window were observed (It should exactly be 75 lb/sq.ft. (5 bars). If it is less than 5 bars, compressor should work more to obtain more pressure. If it 4 bars (low) or 6 bars (high), the compressor would automatically be switched off).
- When the compressor was ready, the machine was plugged in.

### **3.2.3 Packing of chilli powder in bags**

The packaging film or bag of dimension 350×180×150mm was inserted into the "bag shaper" of a suitable size and the flaps at the bottom of the bag were folded correctly. The "bag shaper" with the bag was then placed inside a suitably sized container or mould in to which chilli powder (weighed as 2.0 kg lots) were filled in container or mould. The "bag shaper" was then removed and the flaps on top of the bag were folded, making sure that no creases formed which might compromise correct sealing. The container was then placed on the roller way beside the machine, the height of which (roller way) could be adjusted depending on the height of the bag and the bag was then conveyed into the vacuum chamber. In the vacuum chamber, the open end of the bag was fastened on to the bag stretching bars.

The vacuum chamber was then closed following which the cycle commenced. The stages of operation were automatic and at the end of the work cycle, air would be readmitted inside the chamber and it can be opened. The vacuum packed bag was then removed out of the machine.

## **3.3 OBSERVATIONS RECORDED**

Samples were drawn at 0, 3, 6, 9 and 12 months of storage for determining different quality parameters (Plate 3). Observations were recorded for the following parameters:

### **3.3.1 Physical parameters**

#### **3.3.1.1 Extraneous matter**

It includes inert materials such as sand, stones, excreta etc. alongwith the plant parts such as calyx, loose stalk etc.

#### **3.3.1.2 Filth**

Filth includes contaminants such as hairs, excreta of rat, mouse or other animals, whole insects, parts and excreta, parasitic worms, pollution from excrements of man and animals as well as other extraneous materials which because of their repulsiveness, would not knowingly be eaten or used. The presence of such filth renders food adulterated.

#### **3.3.1.3 Colour**

The colour of the powder was noted visually and was of red colour.

#### **3.3.1.4 Flavour**

The characteristic flavour of chillies is mainly because of the presence of pungent principle, capsaicin. Varieties having high capsaicin content will have strong flavour while, the varieties having low capsaicin content will have mild flavour which does not cause irritation and burning sensation on physical handling. The variety chosen for the investigation i.e. Byadgi Kaddi is a low pungent variety.



Plate 3. Instruments used in the investigation

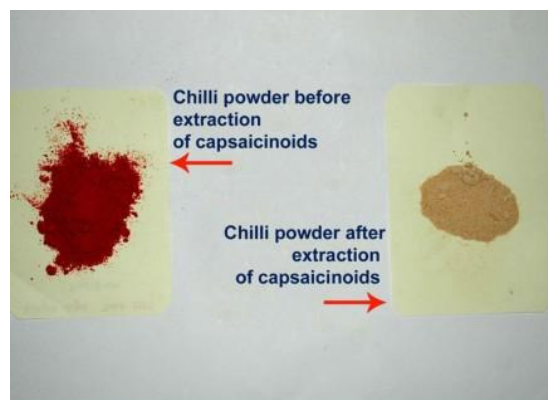


Plate 4. Appearance of chilli powder before and after extraction of capsaicinoids

### 3.3.1.5 Texture

The whole fruits were dried and ground to a fine powder of mesh size 500 microns. The texture of the powder was smooth.

### 3.3.2 Quality parameters

#### 3.3.2.1 Per cent moisture, per cent solids and per cent regain

MB 45 Halogen moisture analyzer (Ohaus, USA) was used for determining the per cent moisture, per cent solids and per cent regain in chilli powder. The instrument works on the principle of thermogravimetry. The moisture was determined from the weight loss of a sample by heating. It has a built - in precision balance and a halogen dryer unit which ensures fast heating of the sample and thus guarantees the rapid availability of the measurement results. 2–3g of the samples were dried at 125°C for 5 min. The samples were dried until all the moisture was evaporated automatically and only the solids are left out. Thus, it gives readings of the per cent moisture and per cent solids directly. The per cent water content in the dehydrated sample was recorded as per cent regain, which is the capacity of the dehydrated sample to absorb moisture.

#### 3.3.2.2 Oleoresin extractable colour

The extractable colour in chilli powder oleoresins was measured by the methodology (method 20.1) specified in the ASTA Analytical methods (Anon., 2004a). Chilli powder (100 mg) was weighed and transferred quantitatively to a 100 ml volumetric flask volume and the volume was made up to 100 ml using acetone. The flask was then shaken well and allowed to stand for 2 minutes. From this, 10 ml of the extract was pipetted into another 100 ml volumetric flask. The volume was made up to 100 ml using acetone and mixed thoroughly. The absorbance of the sample was recorded at 460 nm in a UV visible spectrophotometer (UVS-2700 Labomed, UK). The oleoresin extractable colour was then determined as per the following formula and expressed as ASTA units.

$$\text{ASTA units} = \frac{\text{Absorbance at 460 nm} \times 164}{\text{Sample weight (g)}}$$

#### 3.3.2.3 Total extractable colour

The total extractable colour was determined by measuring the absorbance of an acetone extract at 460 nm. The procedure followed was in accordance to the method 20.1 given by the ASTA Analytical methods (Anon., 2004a).

Ground capsicum sample (100 mg) was accurately weighed and transferred quantitatively to a 100 ml volumetric flask. The volume was then diluted with acetone and capped tightly with a stopper. The flask was shaken well and was allowed to stand for 16 hours at room temperature in dark. The flask was again shaken well and the particles were allowed to settle down. The extractable colour was measured by setting the wavelength on the UV visible spectrophotometer (UVS-2700 Labomed, UK) at 460 nm. The total extractable colour was calculated using the following formula and expressed as ASTA colour units.

$$\text{Total extractable colour (ASTA units)} = \frac{\text{Absorbance at 460 nm} \times 16.4}{\text{Sample weight (g)}}$$

#### 3.3.2.4 Capsaicin content and Scoville Heat Units (SHU) using HPLC

The capsaicin content and SHU were determined as per the method no. 24.2 laid down by ASTA analytical methods (Anon., 2004 b).

##### Principle

HPLC measurement of capsaicin content involves reverse phase HPLC on a C18 column and quantization using UV detection. Mobile phase is 60: 40 acetonitrile: water mixture (with 1% acetic acid). Synthetic capsaicin, N – Vanillyl n – nonanamide, is used as

the standard. Relative amounts of capsaicin, nordihydrocapsaicin and dihydrocapsaicin are calculated by applying specific factors, and from these values the final capsaicinoid content is calculated in Scoville Heat Units (SHU) and ppm (1 ppm ~ 15 SHU). The sum of the SHU values of the capsaicinoids gives the total pungency in SHU.

## **Procedure**

### **a) Apparatus**

- Standard flasks, 50 ml, 100 ml and 200 ml capacity
- Heating mantle of 500 ml capacity with regulator
- HPLC system (Waters)
- Microlitre syringe
- Pipette 10 ml
- Balance readable to 0.01 g
- Glass beads
- Boiling flask, 500 ml
- Whatman No.1 filter paper
- Water cooled condenser

### **b) Reagents**

- Rectified spirit
- Acetonitrile HPLC grade
- Water HPLC grade
- Acetic acid – HPLC grade
- Acetone – HPLC grade
- Standard-N-vanillyl-n-nonamide, 97%.

### **Standard stock solution**

0.1 g of the standard N-Vanillyl-n-nonamide was weighed accurately and dissolved. The volume was then made upto 100 ml with rectified spirit. The stock solution (1000 ppm) thus prepared in the standard flask was wrapped in black cover.

### **Working standard 100 ppm**

10 ml of the stock solution was pipetted to the 100 ml standard flask and volume was made up to 100 ml with rectified spirit. This can be kept under refrigeration in standard flask wrapped in black cover.

### **Sample preparation**

Chilli powder (100 g) was collected as subsample by mixing and quartering the entire sample. 25.0 g of the sample was then weighed accurately in duplicate into 500 ml boiling flask. 200 ml rectified spirit was added into the boiling flask, which was then refluxed gently for 5 hours. Glass beads were also added into the boiling flask to aid boiling. It was then allowed to cool. Whatman no.1 filter paper prewetted with rectified spirit was used to filter 3–4 ml into stoppered test tubes. This sample was injected into HPLC for determination of pungency (Plate 4).

### **Instrument conditions**

**Mobile phase used:** Freshly prepared 60% acetonitrile + 40% water with 1% acetic acid at 0.8 ml/minute flow.

**Detector condition:** Absorbance – 280 nm

**Volume for injection:** 10 µl

## Calculations

The pungency of the chilli sample was calculated in Scoville Heat Units as follows and the total SHU value is expressed by rounding it off to its nearest hundredth place.

- Nordihydrocapsaicin, SHU =  $(N/A) \times (Cs/Wx) \times (HN/RN)$
- Capsaicin, SHU =  $(C/A) \times (Cs/Wx) \times (HC/RC)$
- Dihydrocapsaicin, SHU =  $(D/A) \times (Cs/Wx) \times (HD/RD)$

where,

- A = Average peak area of standard  
Cs = Concentration of standard (mg/ml)  
Wx = Weight of sample (mg/ml)  
N, C and D = Average peak areas for respective capsaicinoids from duplicate injections  
HN, HC and HD = Heat factors for respective capsaicinoids  
RN, RC and RD = Response factors for respective capsaicinoids relative to standard

Capsaicin content in percentage was calculated as follows:

$$\text{Capsaicin content (\%)} = \frac{\text{Total SHU}}{16 \times 10000}$$

### 3.3.2.5 Volatile oil content

The volatile oil content was determined as per the method no.5 laid down by ASTA analytical methods (Anon., 1997b).

#### A. Apparatus

- 1) Round bottom flask with T.S.24/29 ground joint
- 2) Suitable electric heating mantle with regulator
- 3) Clevenger volatile oil traps with T.S.24/29 ground joint
- 4) West condenser, 400 mm length with drip tip and T.S.19/26 ground joints

#### B. Reagents

- 1) Deionized water

#### C. Procedure

The trap was cleaned with chromic acid solution followed by rinsing with deionized water, prior to use. 25 g sample was accurately weighed and transferred quantitatively into a 1000 ml round bottom flask. 500 ml of deionized water was added to this and was then set to boiling in a suitable electric heating mantle. The refluxing was adjusted to one drop per second by adjusting the regulator of mantle. Refluxing was continued until two consecutive readings were taken at one hour interval which showed no change of oil volume in the trap. This was then cooled down to room temperature and oil drops sticking to the sides of the condenser were pulled down to the trap using a steel rod. The amount of oil collected in the trap was recorded in ml.

### 3.3.2.6 Detection of aflatoxins B<sub>1</sub>, B<sub>2</sub>, G<sub>1</sub> and G<sub>2</sub>

Aflatoxin concentrations were determined as per the method no. 24.2 of ASTA analytical methods (Anon., 1997c).

#### Principle

Immunoaffinity columns and post column derivatization in HPLC are the basis for aflatoxin detection. The aflatoxins are extracted from spices using a methanol – water

mixture. It was cleaned up using immunoaffinity column, which binds the aflatoxins present in the sample. The bound toxins are then eluted out and made upto definite volume. It is then injected in HPLC on a C-18 column. The toxins were separated in the HPLC column. The toxin which emerges out of the column is electrochemically derivatized using a Kobra cell for enhanced fluorescence. This is followed by detection using a fluorescence detector.

### **Apparatus**

- Blender jars
- 10 ml volumetric flask
- Para film
- Aflatest pump stand
- Waters 515 HPLC
- Scanning fluorescence detector
- Kobra cell
- 250 ml beakers
- Glass funnels
- 10 ml pipettes
- 50 ml graduated cylinders
- 10-100  $\mu$ l adjustable air displacement pipette

### **Reagents**

- Supelco Aflatoxin Mix Kit-M
- HPLC grade methanol
- 80% methanol / 20% distilled water
- 20% Tween / 80% Deionized distilled water
- 1% Acetic acid in HPLC water
- HPLC water
- Aflatest – P columns
- Chloride Excelar grade
- Fluted filter paper
- Glass fibre filter paper

### **Procedure**

Supelco aflatoxin Mix Kit-M standard was allowed to come to room temperature. 5 ml of methanol was taken in a 10 ml volumetric flask, to which, 25  $\mu$ l of undiluted Supelco standard was added and mixed well. This was then brought to volume with 1% acetic acid in HPLC water solution.

### **Preparation of sample**

The powder was mixed thoroughly and was quartered. A sub sample weighing 100 g was taken. 5 g salt was weighed into a blender jar and 100 ml of methanol : water in the ratio of 80 : 20% added to this. The blender jar was capped and sealed with parafilm and then blended at high speed for 1 minute. The contents were then filtered through a fluted filter into a 250 ml beaker. 10 ml of this filtrate was then pipetted into a 50 ml graduated cylinder and made up to volume with 40 ml of deionised distilled water and mixed thoroughly. Further, the contents of the graduated cylinder were filtered through a glass fibre filter into a 250 ml beaker. This filtrate was used for the aflatest column.

### Immuno affinity column cleanup

The aflatest- P column was attached to the pump stand. 10 ml of the filtrate was pipetted onto the column and was allowed to be absorbed on the column. After having ensured that the sample had passed through the column, it was rinsed couple of times with 10 ml of HPLC water. A 20 ml stoppered test tube was placed under the tip of the column and 1 ml of methanol was added to the column. All the methanol eluent was collected in the test tube. This sample was then injected into HPLC.

### Instrument conditions

- Mobile phase : 63% deionised water with 0.1 g/l KBr and 0.02% nitric acid / 22% methanol / 15% acetonitrile
- Flow rate = 1.1 ml / minute
- Column – Symmetry C-18; 4.6 x 250 mm column
- Volume – 50 µl
- Detection – Excitation at 365 nm, Emission at 464 nm
- Kobra cell @ at 100 µ amps

Millennium 32 @ for data acquisition and processing.

### Calculations

$$\begin{aligned} \text{Aflatoxin content } (\mu\text{g/kg}) &= \frac{a(\text{PG})}{50 \mu\text{l}} \times \frac{1 \text{ ml} \times 100}{100 \text{ ml}} \times \frac{50 \text{ ml}}{10 \text{ ml}} \times \frac{100 \text{ ml}}{w (\text{g}) \times 10^3} \\ &= \frac{\text{PG (conc)}}{25} \quad (\text{where } w = 25) \end{aligned}$$

where,

a = Concentration of aflatoxin PG from HPLC data

w = Weight (g) of sample taken for analysis

50 µl is the injection volume

### 3.3.3 Microbial load

Standard serial dilution plate count technique was followed to determine the microbial load in chilli powder. 1 g chilli powder was transferred to 99 ml water blank and was then serially diluted up to  $10^{-5}$  dilution. One ml aliquot was taken from each of these dilutions and transferred to sterile petriplates under aseptic conditions and the medium was then poured into the petriplates.

Rose Bengal agar (Martin, 1950) medium was used for quantitatively estimating the fungal count, the composition of which is given in Appendix-1. For each dilution used, replications were maintained and the petriplates were incubated at  $30 \pm 1^{\circ}\text{C}$ . The colony count of fungi was recorded after 3 days of incubation. The observations were averaged from the replications under different dilutions. The microbial load was expressed as population of microflora per gram of chilli powder.

## 4. EXPERIMENTAL RESULTS

Investigations on the influence of vacuum packaging and long term storage on the quality of chilli powder were undertaken in the Department of Crop Physiology, University of Agricultural Sciences, Dharwad. Laboratory experiment consisted of five treatments comprising storing powder under vacuum and HDPE bags at room temperature and cold storage under light and dark. Observations were recorded for various physical, quality and microbiological parameters at three months interval for one year (2006-07). The results obtained during the course of investigation are presented in this chapter.

### 4.1 PHYSICAL PARAMETERS

Observations on the extraneous matter at the time of storage and at twelve months of storage are presented in Table 1. It was observed that no extraneous matter was present in the chilli powder at the time of imposing different storage and packaging treatments. During the course of the investigation, it was observed that no extraneous matter was found in the vacuum packed bags stored at either room temperature or cold storage under dark and in the HDPE bags stored in cold storage. However, in the powder stored in HDPE bags at room temperature, insect webbings were observed from six months of storage. By twelve months of storage, it was noted that almost 40% of the powder volume was infested with insect webbings.

It was observed that there was no filth in the powder at the time of treatment imposition (Table 2). As the storage period advanced, insect fragments and emergence of moths were observed particularly at twelve months of storage in the powder stored in HDPE bags at room temperature; whereas, the powder in all the vacuum packed treatments and HDPE bags and stored under cold storage were free from filth content.

Powder form of Byadgi Kaddi variety of chilli used for the investigation had a red colour (Table 3) at the initial stage of storage. At twelve months of storage, vacuum packed bags and HDPE bags kept under cold storage retained the original red colour, while for the powder stored in HDPE at room temperature, the colour had faded and was almost bleached or yellowish near the portions lining the package and was dull faded red colour inside the HDPE bags (Plate 5).

The powder had a characteristic pungent chilli flavour at the time of packing (Table 4). But this flavour was confined only to the vacuum packed powder at twelve months of storage, irrespective of the storage conditions. The powder stored in HDPE at room temperature had an odd flavour and the powder stored in HDPE bags and kept under cold storage though had the characteristic pungent chilli flavour, it was of a lesser intensity.

Fine chilli powder with a mesh size of 500  $\mu$  was used for the study (Table 5). While, there was no change in the texture at twelve months of storage in the vacuum packed treatments and powder stored in HDPE bags under cold storage; while, the powder stored in HDPE bags under room temperature was caked (Plate 5).

**Table 1. Influence of vacuum packaging on extraneous matter at different stages of storage in chilli powder**

Treatments	Storage period (months)	
	0	12
T <sub>1</sub> - VC, RT	Nil	Nil
T <sub>2</sub> - VC, Dark	Nil	Nil
T <sub>3</sub> - VC, CS	Nil	Nil
T <sub>4</sub> - HDPE, RT	Nil	Present*
T <sub>5</sub> - HDPE, CS	Nil	Nil

VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

\* In HDPE bags insect webbings were seen from t=6 and by t=12, almost 40% of the powder volume was infested

**Table 2. Influence of vacuum packaging on filth content at different stages of storage in chilli powder**

Treatments	Storage period (months)	
	0	12
T <sub>1</sub> - VC, RT	Nil	Nil
T <sub>2</sub> - VC, Dark	Nil	Nil
T <sub>3</sub> - VC, CS	Nil	Nil
T <sub>4</sub> - HDPE, RT	Nil	Present*
T <sub>5</sub> - HDPE, CS	Nil	Nil

VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

\*Emergence of moths and insect fragments seen

**Table 3. Influence of vacuum packaging on colour at different stages of storage in chilli powder**

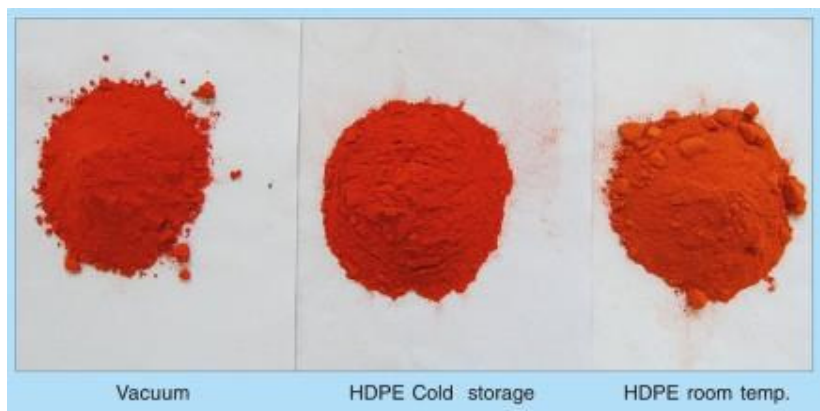
Treatments	Storage period (months)	
	0	12
T <sub>1</sub> - VC, RT	Red	Red
T <sub>2</sub> - VC, Dark	Red	Red
T <sub>3</sub> - VC, CS	Red	Red
T <sub>4</sub> - HDPE, RT	Red	The powder on the inner surface of HDPE lining was almost of bleached red colour / yellowish and inside it was dull faded red colour
T <sub>5</sub> - HDPE, CS	Red	Red

VC = Vacuum packed

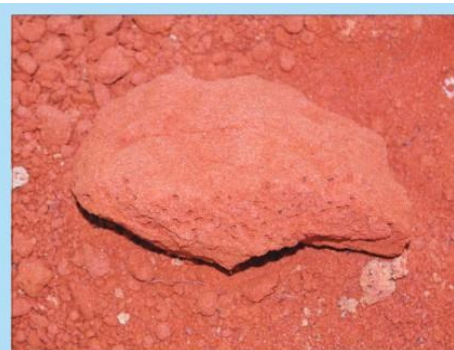
RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene



**Caked appearance of chilli powder after storage in HDPE bag at room temperature**



**Chilli powder infested with Insects after storage in HDPE bag at room temperature**



**Bore holes of insects in HDPE bag stored at room temperature**

**Plate 5. Appearance of powder at the end of 12 months storage**

## **4.2 QUALITY PARAMETERS**

### **4.2.1 Moisture content (%)**

The data on moisture content as influenced by vacuum packaging indicated significant differences among the treatments at all the durations of storage (Table 6, Fig.1). At t=0, vacuum packed powder stored under room temperature had significantly higher moisture (8.55) over all other treatments followed by those under cold storage. No significant difference was observed between the other treatments. The trend slightly changed at three months of storage indicating significantly higher moisture content with powder stored in HDPE bags under cold storage (10.26) which was significantly superior to other treatments. The treatments under vacuum irrespective of storing at room temperature or dark or cold storage did not have significant difference in the moisture content. The powder kept at room temperature and packed in HDPE had significantly higher moisture content compared to the vacuum packed treatments. The same trend was observed with t=6 and t=9 as was observed at three months of storage. The powder kept under cold storage and packed in HDPE continued to maintain significantly higher moisture content even at twelve months of storage period over all other treatments. This treatment was followed by the powder packed in HDPE and kept at room temperature. However, no significant differences were observed between vacuum packed powder under room temperature and dark and between powder stored under dark and cold storage at 12 months of storage.

### **4.2.2 Per cent solids**

The per cent solids differed significantly among the different treatments throughout the storage period (Table 7). It was observed that the vacuum packed powder stored in dark and the powder stored in HDPE at room temperature and cold storage had significantly higher per cent solids at t=0; while, the lowest was recorded in powder stored in vacuum at room temperature (91.45). A similar trend was followed at three, six and nine months of storage wherein, the vacuum packed powder was significantly superior, irrespective of the storage conditions. These treatments were followed by powder stored in HDPE at room temperature and were on par with powder packed in vacuum under cold storage at six months of storage. Significantly lower per cent solids were registered in powder stored in HDPE at cold storage. Even after twelve months of storage, vacuum packed powder under dark and cold storage continued to record significantly higher per cent solids. Significantly lower per cent solids were recorded in powder stored in vacuum at room temperature, which was on par with powder stored in vacuum under dark. These were followed by powder stored in HDPE at room temperature. However, powder stored in HDPE in cold storage recorded significantly lower per cent solids over others (88.19).

### **4.2.3 Per cent regain**

The influence of vacuum packaging on per cent regain presented in Table 8 indicated significant differences between the treatments. It was recorded at t=0, that powder stored in vacuum at room temperature had the highest per cent regain (-9.34), while the lowest was in powder stored in vacuum bags and kept in cold storage (-9.30). The next highest regain was observed in powder stored in vacuum bags kept under cold storage. There was no significant difference between vacuum bags stored under dark and those stored in HDPE at room temperature. The powder stored in HDPE at room temperature was found to be on par with powder stored in HDPE under cold storage. The trend followed at three, six and nine months of storage was observed to be similar wherein, the powder stored in HDPE and kept under cold storage was significantly superior to all the other treatments and no significant differences were observed between the vacuum packed treatments under different storage conditions. After twelve months of storage, powder packed in HDPE bags and stored under cold storage continued the trend of maintaining the highest per cent regain (-13.38). This treatment was followed by powder stored in HDPE bags at room temperature. No significant difference was observed between the vacuum packed powder kept at room temperature and that kept in dark. The powder packed in vacuum and stored under cold storage registered the lowest per cent regain (-8.93) and was found to be on par with vacuum packed powder kept in dark.

**Table 4. Influence of vacuum packaging on flavour at different stages of storage in chilli powder**

Treatments	Storage period (months)	
	0	12
T <sub>1</sub> - VC, RT	Characteristic pungent chilli flavour, free from all odd flavours	Characteristic pungent chilli flavour
T <sub>2</sub> - VC, Dark	Characteristic pungent chilli flavour, free from all odd flavours	Characteristic pungent chilli flavour
T <sub>3</sub> - VC, CS	Characteristic pungent chilli flavour, free from all odd flavours	Characteristic pungent chilli flavour
T <sub>4</sub> - HDPE, RT	Characteristic pungent chilli flavour, free from all odd flavours	Odd flavour
T <sub>5</sub> - HDPE, CS	Characteristic pungent chilli flavour, free from all odd flavours	Characteristic pungent chilli flavour of lesser intensity

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

**Table 5. Influence of vacuum packaging on texture at different stages of storage in chilli powder**

Treatments	Storage period (months)	
	0	12
T <sub>1</sub> - VC, RT	Whole chilli were ground to a fine powder of 500 $\mu$ mesh size	Fine
T <sub>2</sub> - VC, Dark	Whole chilli were ground to a fine powder of 500 $\mu$ mesh size	Fine
T <sub>3</sub> - VC, CS	Whole chilli were ground to a fine powder of 500 $\mu$ mesh size	Fine
T <sub>4</sub> - HDPE, RT	Whole chilli were ground to a fine powder of 500 $\mu$ mesh size	Caky
T <sub>5</sub> - HDPE, CS	Whole chilli were ground to a fine powder of 500 $\mu$ mesh size	Fine

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

**Table 6. Influence of vacuum packaging on moisture content (%) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	8.55 <sup>a</sup>	8.13 <sup>c</sup>	8.77 <sup>c</sup>	8.61 <sup>c</sup>	8.70 <sup>c</sup>
T <sub>2</sub> - VC, Dark	8.54 <sup>a</sup>	8.17 <sup>c</sup>	8.76 <sup>c</sup>	8.68 <sup>c</sup>	8.59 <sup>cd</sup>
T <sub>3</sub> - VC, CS	8.51 <sup>a</sup>	8.37 <sup>c</sup>	8.86 <sup>c</sup>	8.29 <sup>c</sup>	8.19 <sup>d</sup>
T <sub>4</sub> - HDPE, RT	8.52 <sup>a</sup>	9.50 <sup>b</sup>	10.32 <sup>b</sup>	10.20 <sup>b</sup>	10.44 <sup>b</sup>
T <sub>5</sub> - HDPE, CS	8.53 <sup>a</sup>	10.26 <sup>b</sup>	12.09 <sup>b</sup>	11.11 <sup>b</sup>	11.81 <sup>b</sup>
<b>S. Em±</b>	0.009	0.147	0.152	0.100	0.096
<b>C.D. (1%)</b>	NS	0.614	0.635	0.416	0.401

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT

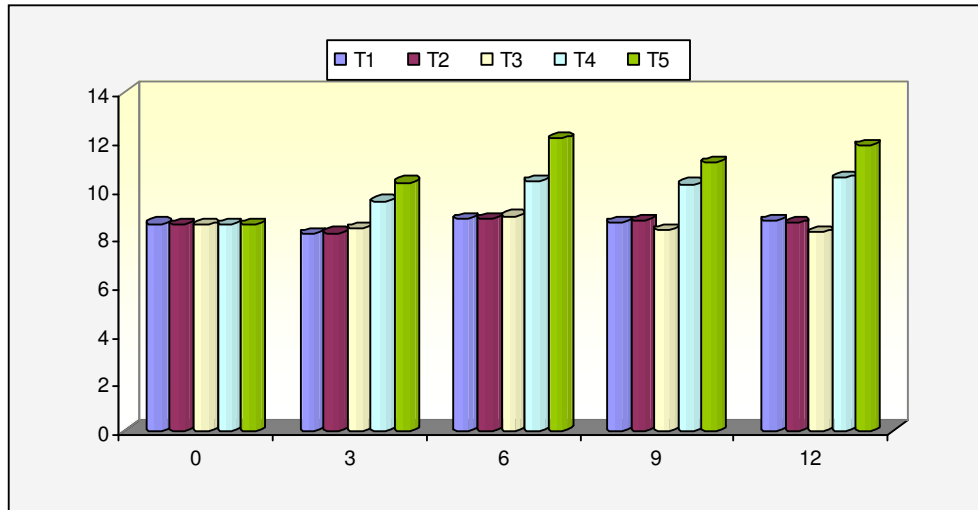
**Table 7. Influence of vacuum packaging on per cent solids at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	91.45 <sup>a</sup>	91.87 <sup>a</sup>	91.23 <sup>a</sup>	91.39 <sup>a</sup>	91.30 <sup>b</sup>
T <sub>2</sub> - VC, Dark	91.46 <sup>a</sup>	91.83 <sup>a</sup>	91.24 <sup>a</sup>	91.32 <sup>a</sup>	91.41 <sup>ab</sup>
T <sub>3</sub> - VC, CS	91.49 <sup>a</sup>	91.63 <sup>a</sup>	91.14 <sup>ab</sup>	91.71 <sup>a</sup>	91.81 <sup>a</sup>
T <sub>4</sub> - HDPE, RT	91.48 <sup>a</sup>	90.50 <sup>b</sup>	89.68 <sup>b</sup>	89.80 <sup>b</sup>	89.56 <sup>c</sup>
T <sub>5</sub> - HDPE, CS	91.47 <sup>a</sup>	89.74 <sup>c</sup>	87.91 <sup>c</sup>	88.89 <sup>c</sup>	88.19 <sup>d</sup>
<b>S.Em±</b>	0.009	0.147	0.152	0.100	0.096
<b>C.D. (1%)</b>	NS	0.614	0.635	0.416	0.401

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT



Moisture content (%)

Storage period (months)

**Figure 1. Influence of vacuum packaging on moisture content (%) at different stages of storage in chilli powder**

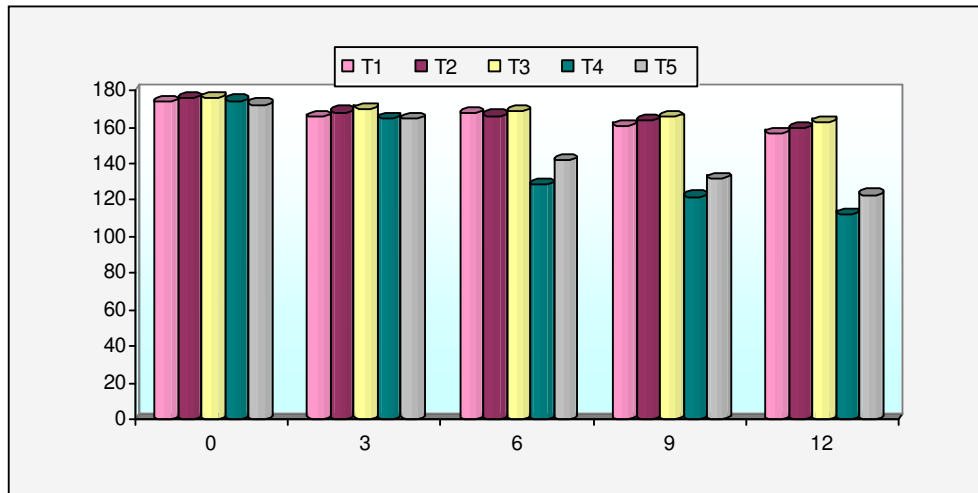
T1 = Vacuum packed, Room temperature

T2 = Vacuum packed, Dark

T3 = Vacuum packed, Cold storage

T4 = High density polyethylene, Room temperature

T5 = High density polyethylene, Cold storage



AST Aunits

Storage period (months)

**Figure 2. Influence of vacuum packaging on oleoresin extractable colour (ASTA Units) at different stages of storage in chilli powder**

**Table 8. Influence of vacuum packaging on per cent regain at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	-9.34 <sup>a</sup>	-8.85 <sup>c</sup>	-9.61 <sup>c</sup>	-9.42 <sup>c</sup>	-9.52 <sup>c</sup>
T <sub>2</sub> - VC, Dark	-9.32 <sup>a</sup>	-8.90 <sup>c</sup>	-9.60 <sup>c</sup>	-9.49 <sup>c</sup>	-9.39 <sup>cd</sup>
T <sub>3</sub> - VC, CS	-9.30 <sup>a</sup>	-9.14 <sup>c</sup>	-9.71 <sup>c</sup>	-9.04 <sup>c</sup>	-8.93 <sup>d</sup>
T <sub>4</sub> - HDPE, RT	-9.31 <sup>a</sup>	-10.50 <sup>b</sup>	-11.50 <sup>b</sup>	-11.36 <sup>b</sup>	-11.65 <sup>b</sup>
T <sub>5</sub> - HDPE, CS	-9.33 <sup>a</sup>	-11.43 <sup>a</sup>	-13.75 <sup>a</sup>	-12.79 <sup>a</sup>	-13.38 <sup>a</sup>
<b>S. Em±</b>	0.011	0.173	0.188	0.207	0.113
<b>C.D. (1%)</b>	NS	0.722	0.785	0.861	0.471

VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT

#### 4.2.4 Oleoresin extractable colour (ASTA Units)

The oleoresin extractable colour differed significantly among different treatments at all the durations of storage (Table 9, Fig. 2). While no significant differences were observed between the treatments at zero and three months of storage period although maximum, oleoresin extractable colour was recorded in vacuum packed powder kept under cold storage at both the stages. At 6 months of storage, no significant difference was recorded between the powder stored under vacuum at room temperature, dark and cold storage and these were found to be significantly superior over other treatments. These treatments were followed by powder stored in HDPE bags under cold storage. The lowest oleoresin extractable colour was however, recorded in powder stored in HDPE bags at room temperature (128.56). The same trend was followed at the nine and twelve months of storage.

#### 4.2.5 Total extractable colour (ASTA units)

The data on total extractable colour presented in Table 10, Fig. 3 indicated significant differences between the treatments at all the stages of storage. Among the treatments, powder stored in vacuum bags and kept under cold storage recorded significantly higher total extractable colour (292.47) at t=0. No significant differences were observed between the vacuum packed powder at room temperature and dark and powder stored in HDPE bags under cold storage. The powder packed in HDPE bags and kept at room temperature was on par with the above treatments and recorded the lowest total extractable colour (286.54).

The trend slightly changed from the third month of storage. The vacuum packed treatments irrespective of the storage conditions and HDPE packed powder kept under cold storage were on par with respect to the total extractable colour at three months of storage. The lower total colour was observed in the powder packed in HDPE bags and kept at room temperature (274.70). At six months of storage, significantly higher total extractable colour was recorded in powder packed in vacuum and stored under cold storage (288.64) and was on par with the vacuum packed bags stored under dark. However, no significant difference was observed between the powder packed in vacuum under dark and stored at room temperature. The lowest total extractable colour was noticed in the powder packed in HDPE bags and kept at room temperature (177.77). The trend followed in the ninth and twelfth month of storage was found to be similar wherein, among the different treatments, the maximum total colour was recorded in vacuum packed bags and kept under cold storage and the minimum in powder stored in HDPE bags kept at room temperature.

**Table 9. Influence of vacuum packaging on oleoresin extractable colour (ASTA Units) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	173.70 <sup>a</sup>	165.40 <sup>a</sup>	167.40 <sup>a</sup>	160.91 <sup>a</sup>	156.47 <sup>a</sup>
T <sub>2</sub> - VC, Dark	175.89 <sup>a</sup>	168.32 <sup>a</sup>	166.13 <sup>a</sup>	163.40 <sup>a</sup>	159.29 <sup>a</sup>
T <sub>3</sub> - VC, CS	176.33 <sup>a</sup>	170.01 <sup>a</sup>	168.52 <sup>a</sup>	165.38 <sup>a</sup>	162.62 <sup>a</sup>
T <sub>4</sub> - HDPE, RT	174.50 <sup>a</sup>	164.81 <sup>a</sup>	128.56 <sup>c</sup>	121.83 <sup>c</sup>	112.51 <sup>c</sup>
T <sub>5</sub> - HDPE, CS	172.35 <sup>a</sup>	164.35 <sup>a</sup>	142.01 <sup>b</sup>	132.02 <sup>b</sup>	123.05 <sup>b</sup>
<b>S. Em±</b>	1.245	1.674	2.157	1.678	1.667
<b>C.D. (1%)</b>	NS	NS	8.989	6.993	6.945

VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT

**Table 10. Influence of vacuum packaging on total extractable colour (ASTA Units) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	288.92 <sup>a</sup>	284.73 <sup>a</sup>	279.62 <sup>b</sup>	244.43 <sup>c</sup>	226.75 <sup>c</sup>
T <sub>2</sub> - VC, Dark	291.35 <sup>a</sup>	288.82 <sup>a</sup>	284.86 <sup>ab</sup>	261.92 <sup>b</sup>	247.15 <sup>b</sup>
T <sub>3</sub> - VC, CS	292.47 <sup>a</sup>	291.92 <sup>a</sup>	288.64 <sup>a</sup>	271.11 <sup>a</sup>	257.66 <sup>a</sup>
T <sub>4</sub> - HDPE, RT	287.54 <sup>a</sup>	274.70 <sup>b</sup>	177.77 <sup>d</sup>	174.21 <sup>e</sup>	147.38 <sup>e</sup>
T <sub>5</sub> - HDPE, CS	287.80 <sup>a</sup>	284.36 <sup>a</sup>	207.62 <sup>c</sup>	204.77 <sup>d</sup>	174.01 <sup>d</sup>
<b>S. Em±</b>	1.117	1.808	1.990	1.725	1.755
<b>C.D. (1%)</b>	NS	7.536	8.293	7.190	7.316

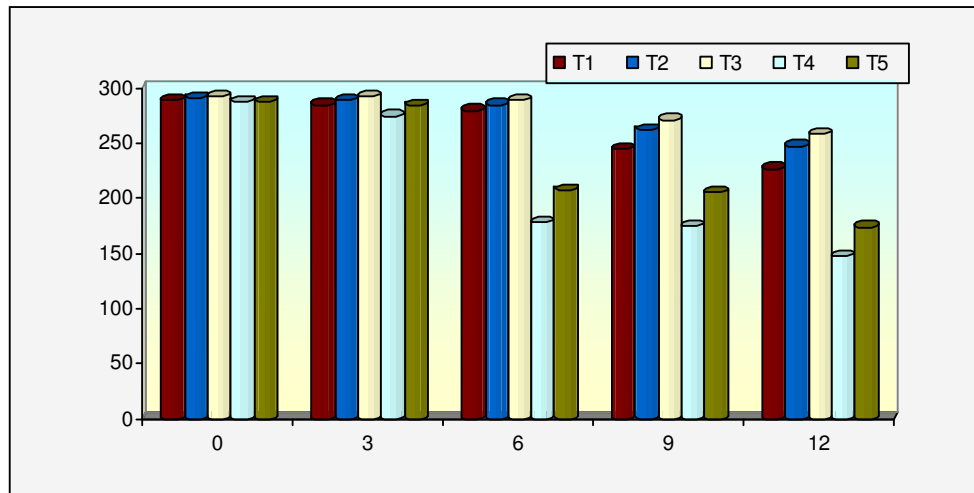
VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

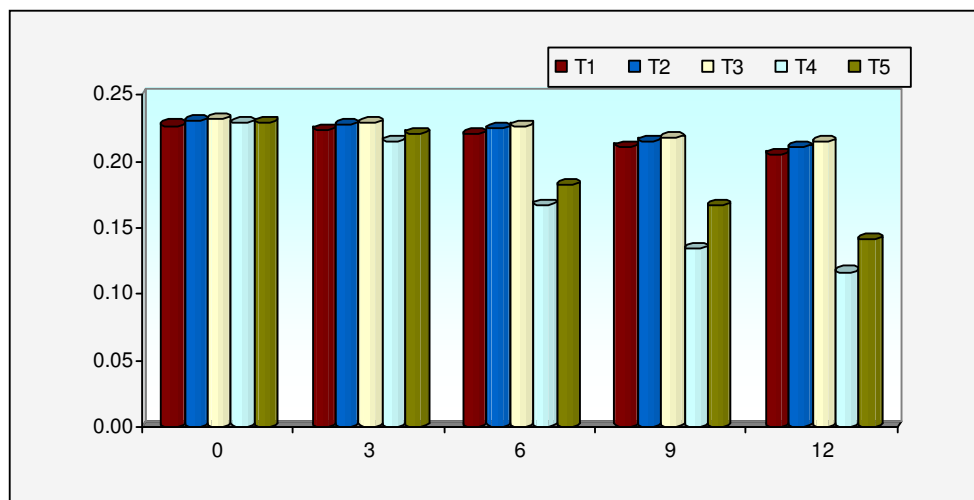
Means in the column followed by the same alphabet do not differ significantly by DMRT



ASTA units Storage Period (months)

**Figure 3. Influence of vacuum packaging on total extractable colour (ASTA Units) at different stages of storage in chilli powder**

T1 = Vacuum packed, Room temperature	T2 = Vacuum packed, Dark
T3 = Vacuum packed, Cold storage	T4 = High density polyethylene, Room temperature
T5 = High density polyethylene, Cold storage	



Capsaicin content (%) Storage period (months)

**Figure 4. Influence of vacuum packaging on capsaicin content (%) at different stages of storage in chilli powder**

#### **4.2.6 Capsaicin content (%)**

The influence of vacuum packaging on capsaicin content (%) presented in Table 11, Fig. 4 indicated significant differences at all the durations of storage. At t=0, no significant difference was observed between the treatments. At three months of storage, no significant differences were observed between vacuum packed powder stored in dark and cold storage and were on par with the powder kept at room temperature and vacuum packed bags and kept in cold storage and stored in HDPE bags. Lowest capsaicin content (0.2148) was registered in powder stored in HDPE bags kept at room temperature, which was also on par with the above two treatments. The treatments of vacuum packed and stored in different conditions did not differ significantly at the six and nine months of storage. Significantly lower capsaicin content was recorded in powder stored in HDPE bags at room temperature at t=6 and t=9.

At twelve months of storage, powder packed in vacuum bags and stored under cold storage recorded significantly higher capsaicin content and was on par with powder packed in vacuum bags and kept in dark. This was followed by powder of vacuum packed and kept at room temperature. But, no significant differences were observed between the vacuum packed treatments stored at room temperature and in dark. However, the lowest capsaicin content of 0.1165 was recorded in the powder stored in HDPE bags and stored at room temperature.

#### **4.2.7 Scoville Heat Limits (SHU)**

The scoville heat units differed significantly between the treatments from t=3 to t=12 (Table 12). At three months of storage, a slight change in the trend was observed. No significant differences were noticed between vacuum packed bags and stored in dark and under cold storage. The next lower SHU was found in powder stored in vacuum bags and kept at room temperature which was on par with powder stored in HDPE bags and kept under cold storage. Among the treatments, the lowest SHU (34300) was recorded in HDPE packed powder kept at room temperature. A similar trend was followed at six, nine and twelve months of storage wherein, the powder packed in vacuum bags and kept at cold storage recorded significantly higher SHU over all other treatments. This was followed by powder packed in vacuum bags and kept under dark. Significantly lower SHU was recorded in the powder packed in HDPE bags and kept at room temperature.

#### **4.2.8 Volatile oil content (% v/w)**

The volatile oil content was in traces in all the vacuum packed treatments and HDPE packed bags stored in cold storage from zero to twelve months of storage (Table 13). While, it was traces up to six months and was not detected after six months of storage in the powder packed in HDPE bags and stored at room temperature.

#### **4.2.9 Aflatoxin content ( $\mu\text{g}/\text{kg}$ )**

Data on aflatoxin content indicated that the aflatoxin B<sub>1</sub>, B<sub>2</sub>, G<sub>1</sub> and G<sub>2</sub> was less than 0.5 ppb in all the treatments at zero and twelve months of storage (Table 14).

**Table 11. Influence of vacuum packaging on capsaicin content (%) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	0.2268 <sup>a</sup>	0.2233 <sup>ab</sup>	0.2203 <sup>a</sup>	0.2111 <sup>a</sup>	0.2052 <sup>b</sup>
T <sub>2</sub> - VC, Dark	0.2303 <sup>a</sup>	0.2270 <sup>a</sup>	0.2244 <sup>a</sup>	0.2153 <sup>a</sup>	0.2101 <sup>ab</sup>
T <sub>3</sub> - VC, CS	0.2312 <sup>a</sup>	0.2285 <sup>a</sup>	0.2265 <sup>a</sup>	0.2171 <sup>a</sup>	0.2145 <sup>a</sup>
T <sub>4</sub> - HDPE, RT	0.2287 <sup>a</sup>	0.2148 <sup>b</sup>	0.1672 <sup>c</sup>	0.1337 <sup>c</sup>	0.1165 <sup>d</sup>
T <sub>5</sub> - HDPE, CS	0.2294 <sup>a</sup>	0.2210 <sup>ab</sup>	0.1819 <sup>b</sup>	0.1664 <sup>b</sup>	0.1411 <sup>c</sup>
<b>S. Em±</b>	0.005	0.003	0.002	0.002	0.001
<b>C.D. (1%)</b>	NS	0.010	0.007	0.007	0.005

VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT

**Table 12. Influence of vacuum packaging on Scoville Heat Units (SHU) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	36300 <sup>a</sup>	35700 <sup>b</sup>	35200 <sup>c</sup>	33800 <sup>c</sup>	32800 <sup>c</sup>
T <sub>2</sub> - VC, Dark	36800 <sup>a</sup>	36300 <sup>a</sup>	35900 <sup>b</sup>	34400 <sup>b</sup>	33600 <sup>b</sup>
T <sub>3</sub> - VC, CS	37000 <sup>a</sup>	36600 <sup>a</sup>	36200 <sup>a</sup>	34700 <sup>a</sup>	34300 <sup>a</sup>
T <sub>4</sub> - HDPE, RT	36600 <sup>a</sup>	34400 <sup>c</sup>	26700 <sup>e</sup>	21400 <sup>e</sup>	18600 <sup>e</sup>
T <sub>5</sub> - HDPE, CS	36700 <sup>a</sup>	35400 <sup>b</sup>	29100 <sup>d</sup>	26600 <sup>d</sup>	22600 <sup>d</sup>
<b>S. Em±</b>	235.7	105.1	67.88	67.69	51.27
<b>C.D. (1%)</b>	NS	437.9	282.9	282.1	213.6

VC = Vacuum packed

RT = Room temperature

CS = Cold storage

HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT

## 4.3 MICROBIOLOGICAL PARAMETER

### 4.3.1 Mold (cfu/g)

The influence of vacuum packaging on mold (cfu/g) presented in Table 15 indicated significant differences between the treatments throughout the storage period (Plate 6). At the time of packing, no significant differences were recorded between the treatments regarding the mold content. At three months of storage, significantly higher mold content (110) was recorded in the powder packed in HDPE bags and kept under cold storage. This treatment was followed by powder packed in vacuum bags and kept under cold storage which was also found to be on par with the powder packed in HDPE bags and kept at room temperature. A minimum value (20) was recorded in vacuum packed bags and stored under dark. The mold was significantly higher in the powder stored in HDPE bags at room temperature at six months of storage. Powder packed in HDPE bag and kept at cold storage registered the next lower count. This treatment was followed by powder packed in vacuum bags and kept under cold storage, while the lowest mold infestation was recorded in vacuum packed bags stored under dark. The same trend was observed at nine months of storage as observed at six months of storage. At twelve months of storage, the maximum mold of 160 was recorded in the powder packed in HDPE bags kept at room temperature, which was on par with the powder kept under cold storage. No mold was observed in the vacuum packed powder, irrespective of the storage conditions.

**Table 13. Influence of vacuum packaging on volatile oil content (% v/w) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	Traces	Traces	Traces	Traces	Traces
T <sub>2</sub> - VC, Dark	Traces	Traces	Traces	Traces	Traces
T <sub>3</sub> - VC, CS	Traces	Traces	Traces	Traces	Traces
T <sub>4</sub> - HDPE, RT	Traces	Traces	Nil	Nil	Nil
T <sub>5</sub> - HDPE, CS	Traces	Traces	Traces	Traces	Traces

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

**Table 14. Influence of vacuum packaging on aflatoxin content ( $\mu\text{g}/\text{kg}$ ) at different stages of storage in chilli powder**

Treatments	Storage period (months)									
	0					12				
	B1	B2	G1	G2	Total	B1	B2	G1	G2	Total
T <sub>1</sub> - VC, RT	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
T <sub>2</sub> - VC, Dark	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
T <sub>3</sub> - VC, CS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
T <sub>4</sub> - HDPE, RT	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
T <sub>5</sub> - HDPE, CS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

**Table 15. Influence of vacuum packaging on mold (cfu/g) at different stages of storage in chilli powder**

Treatments	Storage period (months)				
	0	3	6	9	12
T <sub>1</sub> - VC, RT	170	37 <sup>c</sup> (1.566)*	53 <sup>d</sup> (1.723)	19 <sup>d</sup> (1.277)	0 <sup>b</sup> (0.00)
T <sub>2</sub> - VC, Dark	170	20 <sup>d</sup> (1.286)	40 <sup>e</sup> (1.601)	10 <sup>e</sup> (0.994)	0 <sup>b</sup> (0.00)
T <sub>3</sub> - VC, CS	170	62 <sup>b</sup> (1.792)	80 <sup>c</sup> (1.903)	40 <sup>c</sup> (1.602)	0 <sup>b</sup> (0.00)
T <sub>4</sub> - HDPE, RT	170	60 <sup>b</sup> (1.775)	5900 <sup>a</sup> (3.771)	500 <sup>a</sup> (2.699)	160 <sup>a</sup> (2.207)
T <sub>5</sub> - HDPE, CS	170	110 <sup>a</sup> (2.041)	900 <sup>b</sup> (2.954)	320 <sup>b</sup> (2.505)	110 <sup>ab</sup> (2.045)
<b>S.Em<math>\pm</math></b>	-	0.035	0.015	0.022	0.004
<b>C.D. (1%)</b>	-	0.147	0.065	0.093	0.018

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

Means in the column followed by the same alphabet do not differ significantly by DMRT

\*Figures in parentheses are means of logarithmic transformed values

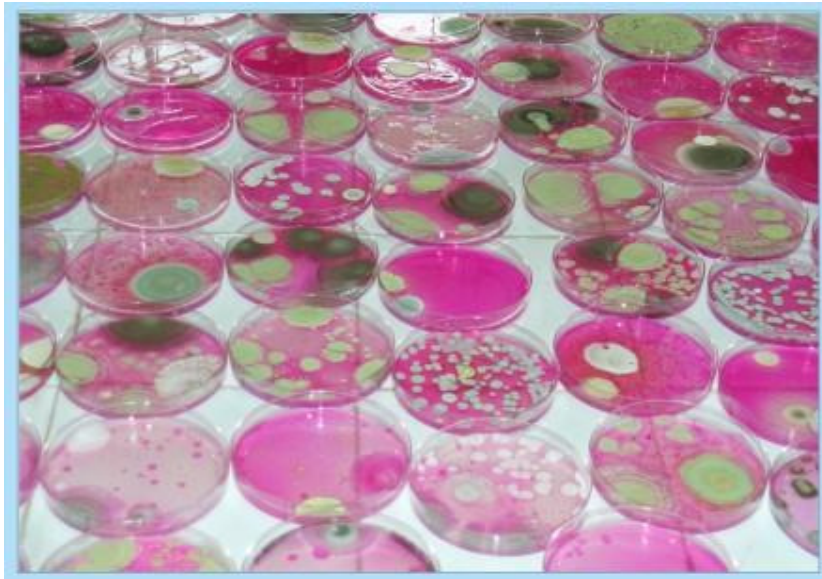


Plate 6. Plate count method for determination of mold population

## 5. DISCUSSION

Chilli, an indispensable spice of every Indian home is also one of the major foreign exchange earners of the country. To tap the export market of this promising spice to its full fledge, it is necessary to comply with the quality requirements of the buying countries. Maintenance of quality during long term storage is important in spices and in value added spice products like chilli powder as they are hygroscopic in nature. An appropriate packaging strategy would help to maintain the quality for a longer period. Hence, an investigation was envisaged to study the influence of vacuum packing and long term storage on the quality of chilli powder.

Studies were undertaken on the different physical, quality and microbiological parameters in chilli powder by storing them in different packaging treatments like vacuum and HDPE under different storage conditions like room temperature, dark and cold storage. The results of the studies are discussed in this chapter with the available literature.

### 5.1 PHYSICAL PARAMETERS

The physical appearance of a product helps the consumer to assess, though not the holistic picture of quality, the extrinsic part of the same. Various importing countries have therefore, defined limits for different physical parameters as well.

In the present investigation, vacuum packed chilli powder irrespective of the storage conditions was found to be devoid of extraneous matter and filth. The reason can be attributed to the vacuum that was created while packing. In the HDPE bags under room temperature, filth and extraneous matter in the form insect webbings and insect fragments were observed from the sixth month and were more prominent by the end of twelfth month. Bore holes due to insect attack were also noticed in the HDPE bags. Observations by Locatelli and Traversa (1989) concluded that a vacuum of 93.3 kPa eliminated the survival of storage insects. The cold temperature maintained in the cold storage might have prevented such developments in the HDPE bags under cold storage.

Colour in chilli and chilli products is due to the presence of carotenoid pigments. These pigments are prone to oxidation when exposed to air (Biacs *et al.*, 1994). The colour of the powder in vacuum packed bags was maintained till the end of the storage period, while the powder in HDPE bags were faded red in colour. This clearly points out the poor barrier property of HDPE bags to air. For a more clear idea of colour deterioration in the various powder treatments, quantification of colour was also done and the results obtained are discussed further in this chapter.

Caking of the powder stored in the HDPE bags under room temperature may also be attributed to insect attack and / or moisture accumulation (Kanner *et al.*, 1977).

### 5.2 QUALITY PARAMETERS

#### 5.2.1 Moisture content (%)

Water activity ( $a_w$ ) is the amount of water present in dehydrated foods which affects several deteriorative reactions in foods such as non enzymatic browning, lipid oxidation, vitamin degradation, enzyme activity, microbial activity and pigment stability (Hardman, 1976; Leung, 1987). Labuza *et al.* (1970) reported that increased moisture content decreases the number of free radicals and thus slows down the rate of oxidation of the carotenoids. Salwin (1959) stated that the water molecules cover the active sites of the dehydrated foods and forms protective film against oxidation. Thus, some moisture content is required in the dehydrated foods for optimum storage stability. But at a higher moisture level of 18 per cent, there is a potential risk of microbial growth (Lee *et al.*, 1992; Slade and Levine, 1991), non enzymatic browning and caking (Kanner *et al.*, 1977; Lee *et al.*, 1991).

When packaging of dehydrated food care considered, the permeability of the package to water vapour is the most important property to be taken into account as dried produce has the capacity to absorb moisture till it is in equilibrium with the surrounding atmosphere (Ranganna, 1986).

In the present investigation, it has been observed that the moisture content varied among the different packaging and storage treatments during the storage period. In general, no appreciable change in moisture content was observed in the vacuum packed bags throughout the storage period. This can be attributed to the impervious nature of the packaging material to moisture. However, a slight increase in the moisture was observed at six and twelve months of storage in the vacuum packed bags under room temperature and dark; while, there was a slight fall in the vacuum packed bags stored under cold storage. But the general trend observed was a more or less stable maintenance of moisture in the vacuum packed bags throughout the twelve months of storage, irrespective of the storage treatments. This indicates the supremacy of the film in maintaining the moisture during storage and thus the quality of the produce.

The storage of powder in the HDPE bags at room temperature shows a fluctuating trend. The change in moisture level of the produce may be due to the changes in the ambient relative humidity at the time of sampling (Appendix 2). Though high density polyethylene bags have low water vapour permeability (Jhaveri, 1998), the results of the investigation have shown that the initial moisture content of the produce is not maintained but has increased thus indicating that HDPE bags may not be a suitable packaging material for long term storage.

The high moisture content observed in HDPE bags under cold storage, when compared to that under room temperature again points out the poor ability of the HDPE to maintain initial moisture. The high moisture content in these bags can be attributed to the high moisture maintained in the cold storage. This explains the high moisture content of the produce from three to twelve months and thus implies the inability of HDPE bags to reduce moisture ingress.

### **5.2.2 Per cent solids**

The results on the influence of vacuum packaging on per cent solids at different stages of storage revealed significant differences between the treatments. However, not much variation was observed with respect to the vacuum packed bags from zero to twelve months of storage, irrespective of whether it was stored at room temperature, dark or cold storage. A slight decline was observed in the vacuum treatments under room temperature and dark while a slight rise under cold storage. The changes in per cent solids can be attributed to the changes in moisture content. By and large, the marginal variation in per cent solids in the vacuum packed bags under different storage conditions is because of the supremacy of the packaging film in preventing the entry of moisture.

Fluctuations in the per cent solids in the powder stored in HDPE bags is due to the changes in the relative humidity of the ambient atmosphere at the time of sampling. Lower values of per cent solids in HDPE bags than vacuum packed bags was because of the high moisture in the HDPE treatments. Comparing the HDPE treatments under room temperature and cold storage, low values were observed in the latter, which is attributed to the high moisture in the powder as the cold storage maintains high humidity.

### **5.2.3 Per cent regain**

The study of the influence of vacuum packaging on per cent regain at different stages of storage in chilli powder indicated a trend that can be explained with respect to the moisture content as this parameter is dependent on the moisture content as well. The variation observed in the moisture content between treatments corroborate with the fluctuations in per cent regain in the respective treatments. Thus, the minor variation in per cent regain from zero to twelve months of storage in vacuum packed treatments may be because of the barrier properties of the packaging film to moisture.

### **5.2.4 Oleoresin and total extractable colour (ASTA units)**

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). In chillies, pigments like capsanthin and capsorubin contribute to its unique red colour. This is one of the main attributes which determine its value in the spice market and this necessitates its maintenance in storage.

The total extractable colour did not change appreciably up to three months of storage, irrespective of the packaging and storage conditions. The decline was substantial in HDPE bags stored under room temperature at t=6 (38.1%) (Table 16, Fig. 5), while in the vacuum packed bags, the decline was very meager, irrespective of the storage conditions. A similar trend as that of oleoresin extractable colour was observed in the total colour wherein, at the end of storage period, minimum colour decline was in the vacuum packed bags stored under cold storage (11.9%), while the maximum in HDPE bags kept at room temperature (48.7%).

Oleoresin extractable colour forms a fraction of total extractable colour. It was observed from the study that there were not much changes in the oleoresin extractable colour in the vacuum packed bags up to six months of storage. While, in the HDPE bags stored under room temperature at six months there was a decline of nearly 26.3 per cent (Table 17, Fig. 6) in the oleoresin extractable colour and this treatment continued to have the least oleoresin extractable colour till the end of the storage period.

Among the vacuum packaged treatments stored under light and dark, better colour retention was recorded in the powder stored in dark. These findings corroborated with the findings of Van Blaricom *et al.* (1951), who reported that chilli samples stored in dark retained colour much longer than those stored in light. Although, the carotenoids are sensitive to light, this sensitivity depends on the presence of oxygen and light which act as catalysts to induce oxidation (Bunnell and Bauernfeind, 1962). This is in close agreement with the findings in the present investigation where the vacuum packed treatments retained more colour values over HDPE treatments because of the impervious nature of the film to air throughout the storage period. Jhaveri (1998) stated that the permeability of HDPE bags to gases is relatively high. Again, the findings of the investigation are in line with the review by Jhaveri (1998), as more colour deterioration was observed in HDPE bags.

Irrespective of whether the powder was packed in HDPE bags or vacuum bags, it was observed that more colour was maintained in the treatments under cold storage. The results of Lease and Lease (1956) who reported that the loss of colour was markedly slower at low temperature storage stand in conformity with the present findings.

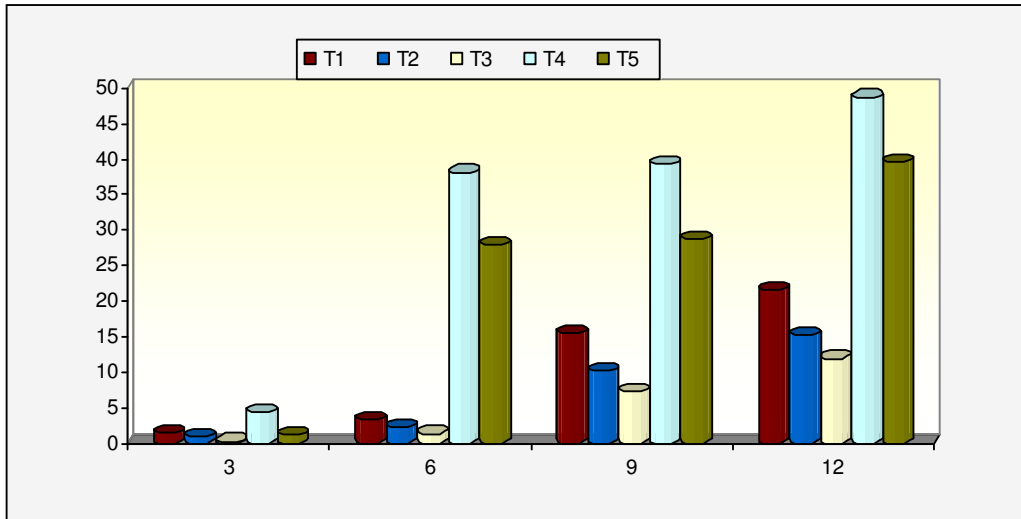
Results from the studies of Lee *et al.* (1992) indicated that lowering the storage temperature and reducing the package free space volume, improves carotenoids retention. The present investigation stands in close agreement with the results of Lee *et al.* (1992), as the maximum colour retention was recorded in the vacuum packed powder stored under cold storage. Throughout the study, colour deterioration was also observed in the vacuum packed bags, but to a lesser extent, which may be due to the residual air was present in the vacuum bags after packaging.

**Table 16. Influence of vacuum packaging on per cent decline in total extractable colour (over initial t=0) in chilli powder at different stages of storage**

Treatments	Storage period (months)			
	3	6	9	12
T <sub>1</sub> - VC, RT	1.5	3.2	15.4	21.5
T <sub>2</sub> - VC, Dark	0.9	2.2	10.1	15.2
T <sub>3</sub> - VC, CS	0.2	1.3	7.3	11.9
T <sub>4</sub> - HDPE, RT	4.4	38.1	39.4	48.7
T <sub>5</sub> - HDPE, CS	1.2	27.9	28.8	39.5

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

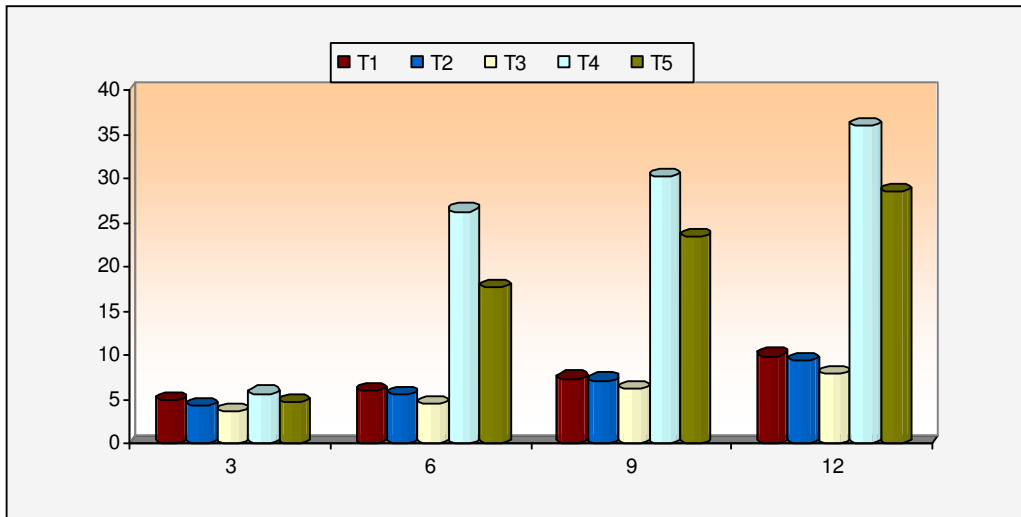


Per cent decline

Storage period (months)

**Figures 5. Influence of vacuum packaging on per cent decline in total extractable colour (over initial t=0) at different stages of storage in chilli powder**

T1 = Vacuum packed, Room temperature	T2 = Vacuum packed, Dark
T3 = Vacuum packed, Cold storage	T4 = High density polyethylene, Room temperature
T5 = High density polyethylene, Cold storage	



Per cent decline

Storage period (months)

**Figure 6. Influence of vacuum packaging on per cent decline in oleoresin extractable (over initial t=0) at different stages of storage in chilli powder**

**Table 17. Influence of vacuum packaging on per cent decline in oleoresin extractable colour (over initial t=0) in chilli powder at different stages of storage**

Treatments	Storage period (months)			
	3	6	9	12
T <sub>1</sub> - VC, RT	4.8	5.9	7.3	9.9
T <sub>2</sub> - VC, Dark	4.3	5.5	7.1	9.4
T <sub>3</sub> - VC, CS	3.6	4.4	6.2	7.8
T <sub>4</sub> - HDPE, RT	5.6	26.3	30.2	36.0
T <sub>5</sub> - HDPE, CS	4.6	17.6	23.4	28.6

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene

### 5.2.5 Capsaicin content and Scoville Heat Units (SHU)

The other unique property of chilli is its pungency which is due to the accumulation of capsaicin. The present study revealed no appreciable reduction in the capsaicin content and SHU values even up to twelve months of storage in vacuum packed bags, regardless of the storage conditions. However, the per cent reduction in capsaicin and SHU values were less in cold storage in both the vacuum and HDPE treatments when compared to the storage at room temperature.

Van Blaricom and Martin (1951) reported that capsaicin is retained for longer period and is not correlated with colour retention. Studies by Kim *et al.* (2002) on Korean red pepper have also concluded that capsaicinoids in red pepper were not related to colour stability. The present studies also corroborate with the above literature. At six months of storage, it was observed in the vacuum packed bags under room temperature that the reduction in total colour was 3.2% while that in capsaicin was 2.8% (Table 18, Fig. 7). This trend continued till twelve months of storage, irrespective of the storage treatments of the vacuum packed bags. At t=12, a decline of 21.5% was observed in total colour while only 9.5% reduction in capsaicin in the vacuum packed bags kept in room temperature. Throughout the storage period, it was observed that the maximum decline in capsaicin (49%) was with the powder packed in HDPE bags and stored at room temperature.

### 5.2.6 Aflatoxin content (µg/kg)

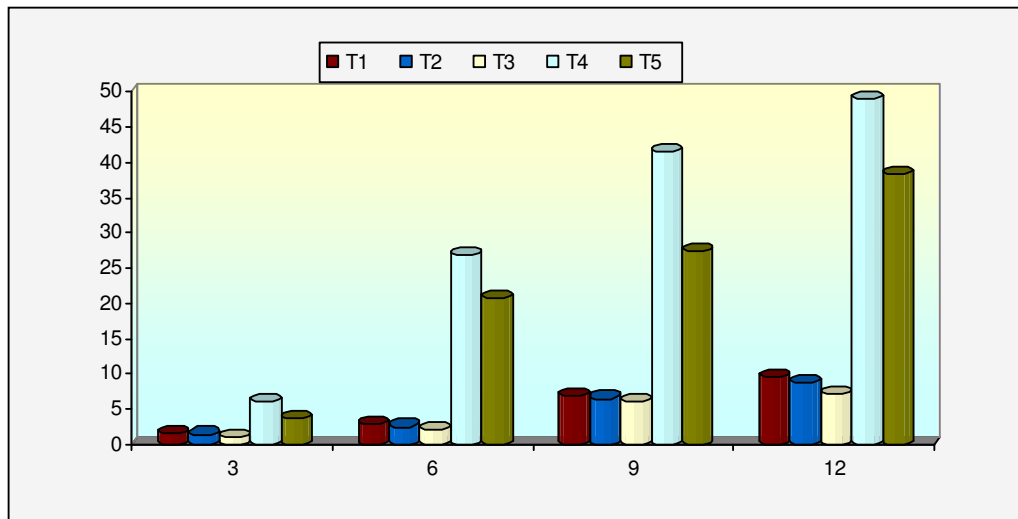
The aflatoxin B1, B2, G1, G2 content in all the treatments from zero to 12 months of were below 0.5 ppb. This indicated that the samples procured for the investigation did not have any aflatoxin content and did not come in contact with any such surface that can contaminate the samples. This was because, due care was taken from harvesting to drying, packaging, and storage, so as not to contaminate the samples.

**Table 18. Influence of vacuum packaging on per cent decline in capsaicin content (over initial t=0) in chilli powder at different stages of storage**

Treatments	Storage period (months)			
	3	6	9	12
T <sub>1</sub> - VC, RT	1.5	2.8	6.9	9.5
T <sub>2</sub> - VC, Dark	1.4	2.5	6.5	8.7
T <sub>3</sub> - VC, CS	1.1	2.0	6.1	7.2
T <sub>4</sub> - HDPE, RT	6.0	26.8	41.5	49.0
T <sub>5</sub> - HDPE, CS	3.6	20.7	27.4	38.4

VC = Vacuum packed  
CS = Cold storage

RT = Room temperature  
HDPE = High density polyethylene



Per cent decline

Storage period (months)

T1 = Vacuum packed, Room temperature	T2 = Vacuum packed, Dark
T3 = Vacuum packed, Cold storage	T4 = High density polyethylene, Room temperature
T5 = High density polyethylene, Cold storage	

**Figure 7. Influence of vacuum packing on per cent decline in capsaicin content (over initial t=0) at different stages of storage in chilli powder**

## **MICROBIOLOGICAL PARAMETER**

### **5.3.1 Mold (cfu/g)**

The mold growth showed an irregular trend between different durations of samplings emphasizing that it was dependent on the ambient relative humidity and temperature particularly in the period preceding storage and time of sampling. The study revealed that a relatively lower mold population, in the vacuum packed treatments. Sanjeev and Ramesh (2006) have reviewed that although vacuum packaging can be used to extend the shelf life and keeping quality of food, it depends on the residual oxygen in the package head space. Several studies have shown that aerobic *Pseudomonas* spp. and *Aspergillus* sp. can grow in an atmosphere of 1-2% oxygen (Dallyn and Everton, 1969). This supports the present study, as mold growth was also observed in the vacuum packed treatments. This can again be corroborated with the results obtained from the study on colour in the vacuum packed treatments as colour deterioration was observed in the same from zero to twelve months of storage because of the oxidation of carotenoids.

Among the vacuum packed treatments, the highest mold count was observed in the treatment stored in cold. This may be because of the high humidity maintained in the cold storage.

The powder stored in HDPE bags at room temperature recorded higher mold population than the others. The fluctuations in the mold growth can be attributed to the changes in the ambient relative humidity. The powder stored at cold storage did not record much variation in the mold count as more or less same humidity was maintained in the cold storage.

## **5.4 FUTURE LINE OF WORK**

Based on the results of the present investigation, it is suggested to conduct future research on the following aspects.

- The investigations were conducted using transparent polyethylene film and stored in dark and hence, it is proposed to investigate the influence of vacuum packaging in chilli powder using opaque polyethylene film.
- Further studies should also focus on the influence of vacuum packaging in other spices, spice products and other food products.
- The combined effect of vacuum packaging and use of oxygen scavengers while packing can also be looked into.
- Studies can also be directed towards the use of oxygen scavenging films while packing and its influence on long term storage in different food commodities.

## 6. SUMMARY AND CONCLUSIONS

Investigations were undertaken to study the influence of vacuum packaging and long term storage on quality of chilli powder. The experiment was conducted at the Department of Crop Physiology, University of Agricultural Sciences, Dharwad. The study consisted of five treatment combinations of packing chilli powder under vacuum and in HDPE bags and storage at room temperature, light, dark and cold storage. The salient findings of the investigations are summarized hereunder.

- Vacuum packaging of chilli powder has been found to be highly beneficial for storing chilli powder over packaging in HDPE bags.
- No extraneous matter or filth content was observed in the vacuum packed bags throughout the storage period. While, in the HDPE bags at room temperature, insect webbings, emergence of moths and insect fragments were seen particularly at the end of storage period.
- The characteristic pungent chilli flavour, red colour of the powder and texture retained in the vacuum packed bags at all the stages of storage. In HDPE bags kept at room temperature, it was noticed that the colour had bleached on the inner surface of the HDPE lining and the colour was dull faded red colour inside the bags. The powder had an odd flavour and was caked, when observed at the end of the storage period. The HDPE bags under cold storage had the characteristic pungent chilli flavour, but was of lesser intensity.
- The moisture content of the powder was maintained in the vacuum packed bags as that of the initial until 12 months of storage, while the moisture content fluctuated greatly in the HDPE bags stored at room temperature depending on the ambient relative humidity and temperature. The moisture content in the HDPE bags kept in cold storage had the highest values.
- The oleoresin extractable colour and total extractable colour were very high in the vacuum packed treatments throughout the storage period. The per cent decline at 12 months of storage ranged from 7.8 to 9.9 for oleoresin extractable colour and 11.9 to 21.5 for total extractable colour for the vacuum packed treatments depending on the storage conditions. The least reduction was observed in the cold storage treatments compared to the storage at room temperature. While for HDPE bags, the values ranged from 28.6 to 36.0 for oleoresin extractable colour and 39.5 to 48.7 for total colour at the end of the 12 months of storage. Hence, it is evident that there is a great reduction in the colour when stored in HDPE bags. However, the vacuum packed bags proved their supremacy in maintaining the colour throughout the storage period.
- The capsaicin content and Scoville Heat Units (SHU) were significantly higher in the vacuum packed bags. The least reduction was observed in the powder stored under cold storage. At the end of the storage period, per cent reduction in the capsaicin content ranged from 7.2 to 9.5 depending on the storage conditions. In the HDPE bags, it was observed that the per cent reduction ranged from 38.4 to 49.0 per cent for capsaicin content at the end of the storage period. Thus, it clearly indicates that it is possible to maintain the capsaicin content with least reduction by storing the powder under vacuum.
- The aflatoxin content was less than 0.5 ppb in all the samples, which is much below the permissible limits.
- The vacuum packed treatments had less microbial growth and were well within the permissible limits. While, the powder in HDPE bags had a high microbial load.

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## APPENDIX I

### Martin's Rose Bengal Agar (Martin, 1950)

Dextrose	10.0 g
Peptone	5.0 g
Potassium dihydrogen phosphate	1.0 g
Magnesium sulphate	0.5 g
Rose bengal	1 : 30,000 parts
Streptomycin	30 µg
Agar	15.0 g
Distilled water	1000 ml
Streptomycin solution is to be added just before plating	

**Appendix II. Data on temperature and relative humidity (February 2006 to February 2007)**

Date	Temperature (°C)		Relative humidity (%)
	Maximum	Minimum	
1-Feb-06	30.1	11	67
2-Feb-06	30.7	12	70
3-Feb-06	31.1	12.7	65
4-Feb-06	30.8	11.9	66
5-Feb-06	31	14.7	61
6-Feb-06	31.2	11.7	51
7-Feb-06	31	12.4	51
8-Feb-06	31.2	13.4	58
9-Feb-06	30.8	13.1	60
10-Feb-06	30	12.3	49
11-Feb-06	29.7	13.4	56
12-Feb-06	29.9	15.9	50
13-Feb-06	30.9	13.2	47
14-Feb-06	31.3	17.6	53
15-Feb-06	31.9	13.8	57
16-Feb-06	32.8	14.8	81
17-Feb-06	33.1	17.5	98
18-Feb-06	34.1	16.5	94
19-Feb-06	34.4	16.9	58
20-Feb-06	34.2	16	56
21-Feb-06	35.4	19.8	50
22-Feb-06	35	16.1	58
23-Feb-06	34	16.4	48
24-Feb-06	25	17.4	47
25-Feb-06	35.4	15.5	40
26-Feb-06	35	15.5	55
27-Feb-06	33.8	15.5	61
28-Feb-06	34	18.1	76
1-Mar-06	34.2	14.2	93
2-Mar-06	34.2	18.9	96
3-Mar-06	34.5	19.5	82
4-Mar-06	34.2	20	77
5-Mar-06	34.7	19	86
6-Mar-06	34.2	15.5	55
7-Mar-06	34.2	16	57
8-Mar-06	35	17.2	45
9-Mar-06	34	17.4	61
10-Mar-06	35.5	17.6	87
11-Mar-06	25.2	15	74
12-Mar-06	30.5	13.8	79
13-Mar-06	29.5	16.4	78
14-Mar-06	31.5	15.1	68
15-Mar-06	31.5	16.2	62
16-Mar-06	32	15.6	54
17-Mar-06	32.2	15.2	51
18-Mar-06	32.8	14.8	66
19-Mar-06	33.5	18.2	62
20-Mar-06	34.5	20.8	62
21-Mar-06	34.8	20.2	70
22-Mar-06	35.2	21.6	47
23-Mar-06	36.4	14.6	36
24-Mar-06	36.2	19.2	37
25-Mar-06	37	18.5	44
26-Mar-06	37.2	20.2	83
27-Mar-06	36.8	19.5	66
28-Mar-06	35.8	18.4	41
29-Mar-06	36.2	20.6	45
30-Mar-06	36.7	21	85
31-Mar-06	36.1	20.9	83

# **INFLUENCE OF VACUUM PACKAGING AND LONG TERM STORAGE ON QUALITY IN CHILLI POWDER**

**REMYA JOSEPH**

**2007**

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## **ABSTRACT**

Investigations were undertaken in the Department of Crop Physiology, University of Agricultural Sciences, Dharwad during 2006-07 to study the influence of vacuum packaging and long term storage on quality of chilli powder. The laboratory experiment consisted of five treatment combinations comprising of storing powder under vacuum and HDPE bags at room temperature and cold storage under light and dark. Byadgi Kaddi cultivar of chilli, dried and powdered to a mesh size of 500  $\mu$  was used for the study. Observations were recorded for various physical, quality and microbiological parameters at three months interval upto 12 months of storage.

Results revealed that there were no changes with respect to the physical parameters like colour, texture and flavour in the vacuum packed bags and HDPE bags kept under cold storage throughout the storage period. While in the HDPE bags at room temperature, insect webbings were seen at the end of the storage period. The characteristic pungent chilli flavour, red colour and texture were retained in the vacuum packed bags at all stages of storage. In the HDPE bags under room temperature, the colour faded to a dull red, was caked in texture and had an odd flavour. The moisture content was maintained in the vacuum packed bags throughout the storage period, while it fluctuated greatly in the HDPE bags stored at room temperature. The oleoresin extractable colour, total extractable colour, capsaicin content and SHU values were significantly higher in the vacuum packed treatments. Aflatoxin content was less than 0.5 ppb in all the treatments. The vacuum packed treatments had less microbial growth and were within the permissible limits while, the powder in HDPE bags under room temperature had a high microbial load.