

Effect of drying methods and packaging materials on storage stability and quality of chillies

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Technology of Kashmir**

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**Effect of drying methods and packaging materials on
storage stability and quality of chillies**

**Towseef Ahmad Wani
(2011-370-D)**



Thesis

Submitted to

**The Faculty of Horticulture
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in partial fulfilment of requirement for the award of the degree of
Doctor of Philosophy in Post Harvest Technology**

2015

Dedicated

*To my
beloved Parents*

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Post Harvest Technology,
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-:o:-

Certificate – I

This is to certify that the thesis entitled, **“Effect of drying methods and packaging materials on storage stability and quality of chillies”** submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Post Harvest Technology**, to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Towseef Ahmad Wani (Regd. No. 2011-370-D)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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ABSTRACT

The investigation entitled “Effect of drying methods and packaging materials on storage stability and quality of chillies” was carried out in the Division of Post Harvest Technology, SKUAST-Kashmir, Shalimar during the years 2011-12 and 2012-13 to select a best pre-treatment and drying method for getting an acceptable dried chilli which remains stable during storage. The best treatment combination was carried over in preparing chilli powder which was packed in three different packaging materials namely metallised laminated polyester (MLP), low density polyethylene (LDPE) and vacuum packed (VP) in MLP pouches and evaluated for various chemical parameters and water activity. Physical parameters recorded revealed that fresh red chilli had an average length of 11.21 cm, average breadth of 1.57 cm, average fruit weight of 9.060 g, while as seed percentage was 34%. Chemical composition of fresh chilli (Kashmir Long 1) revealed that it contained 80.68% wb (417.75 %db) moisture and 0.64 per cent reducing sugar, 49.40 mg/100g ascorbic acid, 0.38 % capcaisin and 98.37 ASTA units capsanthin. The quality with respect to physico-chemical properties of dried whole chilli samples and chilli powder was monitored by drawing periodic samples during ambient storage period of 120 days. In case of solar tunnel drying the highest ascorbic acid (41.08mg/100g), capsanthin (121.51 ASTA units),

capsaicin (1.07%) and reducing sugar (0.62 %) was recorded in treatment T₇ at 0 days of storage. The treatment T₀ (Control) recorded the highest moisture (14.45%db) and non enzymatic browning (0.15) in sun dried chilli at 120 days of storage. In mechanical dried chilli samples the highest ascorbic acid (55.51mg/100g), capsaicin (1.09%), reducing sugar (0.61%) was recorded in treatment T₇ (2.5% Potassium carbonate+1% ground nut oil+ 0.1% gum acacia +0.001% BHA per liter (15 min)) in chilli dried at 45°C. The highest capsanthin (134.02 ASTA units) and capsiacin (0.93%) of dried chilli powder was recorded in treatment combination T₇ dried in mechanical dryer and packed in vacuum packaging. In general pre-treatment T₇, mechanical drying at 45°C and vacuum packaging was found best from all the experiments. Based on various model fitting criterion, the mechanical drying behaviour of whole chillies at 45, 55 and 65°C was found to comply page model, Newton model, Henderson-Pabis model.

Key words: Capsiacin, Chilli, Drying kinetics, Kashmir Long-1.

Signature of the Student

Signature of Major Advisor

Dated _____

Dated _____

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Chapter – 1

INTRODUCTION

Chilli (*Capsicum annum* L.) from family Solanaceae, is one of the universal spices and is grown in almost all states of India for domestic market and export purpose. The native home of chilli is considered to be Mexico with secondary origin of Gautemala (Sigge *et al.*,2001). In India, only two species viz. *Capsicum annum* and *Capsicum frutescens* are known and most of the cultivated varieties belong to the species *Capsicum annum* (Pal *et al.*,2008). Chilli was introduced in India by the Portugese in Goa in the middle of 17th century and since then it had rapidly spread throughout the country (Topuz and Ozdemir, 2007). Chilli is raised over an area of 1832 thousand hectares in the world, with a production of 2959 thousand tons (Satyanarayana and Vengaih, 2010). Major chilli growing countries are India, China, Indonesia, Korea, Pakistan, Egypt, Mexico, USA, Italy and Hungary. India is the world leader in chilli production followed by China and Pakistan. Andhra Pradesh is the largest producer of chilli in India and contributes about 26 per cent to the total area under chilli, followed by Maharashtra (15%), Karnataka (11%), Orissa (11%), Madhya Pradesh (7%) and other states contributing nearly 22 per cent to the total area under chilli (Akpinar, 2002).

Chilli has health benefiting alkaloid compound in them known as capsaicin which gives strong spicy pungent character (Sadhna *et al.*,2006). The colour of chilli is due to the presence of red pigmented carotenoids, the main being capsanthin, capsorubin, zeaxanthin and cryptoxanthin. These pigments are stable in intact plant tissue. However during drying and grinding to spice powder carotenoids show auto oxidation due to heat, light and oxygen (Mangaraj *et al.*,2001). It is a rich source of vitamin A, C and E. Recently Russian scientists have identified Vitamin P in green chillies which is considered to be important as it protects from secondary irradiation injury. It also prevents the heart disease by dilating blood vessels. Chilli is an important ingredient in day to day curries,

pickles and chutneys, oleoresins, sauce and essence are prepared from chillies (Gallardo *et al.*,2010).

Harvesting is done when the pods are well ripened and partially withered on the plant itself. The harvested pods are kept in heaps either indoor or in shade away from direct sun light for 2 or 3 days so as to develop uniform red colour and then dried in the sun by spreading them on clean dry polythene sheets, cemented/concrete drying yards etc. Pods are spread out in thin layers for uniform drying with frequent stirring to prevent mold growth and discolouration. The initial moisture content of chillies ranged from 300-400 per cent (db) which is very high for processing and storage. Therefore reduction of moisture in chilli to a safe level of 8-9 per cent (db) becomes necessary before their processing and storage (Ahmad and Shivare, 2001). Improved drying system could be used to ensure cleanliness and uniform colour of the product. The dried pods are heaped and covered by clean gunny bags/polythene sheets (Famurewa *et al.*,2006; Hossain and Bala, 2002).

The moisture sorption isotherms describes relationship between water activity and the equilibrium moisture content for a food product to a constant pressure and temperature. These help in the optimisation of process such as design, packaging and processing problems for modelling moisture changes which occur during drying, it also helps in predicting shelf life stability (Figen and Mustafa, 2001).

In fresh chilli oxidation is catalysed by peroxidases. Most of the vitamins, and pigments are lost during drying. So drying has been used for decades in chemical and food processing industries for long term preservation of the final product (Santombi and Sharma, 2008). Drying is defined as the process of moisture removal due to simultaneous heat and mass transfer. Moreover it's one of the oldest methods of food preservation (Gupta *et al.*,2002). The chilli is very sensitive to temperature. Normally, conventional hot air drying temperature is maintained between 50-70°C. Due to the long drying process, the problem of

darkening of colour, loss in flavour and decrease in rehydration ability occurs. Longer shelf life, product diversity and substantial volume reduction are the reasons for popularity of dried fruits and vegetables and this could be expanded further with improvements in product quality and process applications (Jasim and Shivare, 2001). To prevent significant quality loss and to achieve fast and effective dehydration various drying techniques have been developed. These improved methods could increase the current degree of acceptance of dehydrated foods in the market (Arora and Bharti, 2005).

The packaging of chillies is also important in the retention of colouring pigments of dried chillies and vitamin A. Low Density Polyethylene (LDPE- 37 µm), High Density Polyethylene (HDPE-75µm) and Metallised Polyester Polyethylene (MPP-12µm) are various packaging materials used to store dried chillies for prolonged period of time (Pura *et al.*,2001).

Control of browning is one of the most important issues in food industry as colour is significant attribute of food which influences consumer decision and brown foods are seen as spoiled (May *et al.*,1999). Therefore several pretreatments and methods can be applied to avoid enzymatic browning (Ajaykumar *et al.*,2012). An improved method is therefore essential to reduce these losses. To overcome this problem, the mechanical drying becomes essential. Mechanical drying produces more consistent quality product taking less time and minimizing crop losses (Wiriya *et al.*,2009). With appropriate choice of temperature and time variation, it is possible to reduce the overall colour change while maintaining higher drying rates (William *et al.*,2008).

Chilli is commercial cash crop of Kashmir valley, owing to its demand and market value the crop is presently grown in various traditional chilli growing belts and is being promoted in other areas under vegetable production scheme of Department of Agriculture. The harvested chillies are dried under unhygienic conditions on road side, or on roof tops. Sudden onset of rains, deteriorates whole crop due to fungal infestations. The uncontrolled sun drying process takes long

time, and product is subjected to contamination by dust, dirt and microorganisms. There is need to develop appropriate scientific drying technology for preserving the quality characteristics of Kashmir chillies for better marketing.

Keeping this in view the comparative studies of various chilli drying methods and the pre-treatments used for retention of quality parameters of whole chillies and chilli powder in various packaging material were studied during 120 days of ambient storage. Therefore, the present study was undertaken to study the drying and storage behaviour of chillies with the following objectives:

- 1) To study effect of different pre-treatments on sun and solar drying characteristics and storage quality of whole chillies Kashmir Long-1.
- 2) To study effect of different pre-treatments and mechanical drying temperatures on storage quality of whole chillies Kashmir Long-1.
- 3) To study the storage quality parameters of chilli powder prepared by best method of drying using best pre-treatment by different packaging materials during ambient storage.

Chapter – 2

REVIEW OF LITERATURE

The red pepper has been used since ancient times as a source of pigment to enhance or change food colour. Its red colour is one of the prime factors on which the commercial value of the product rests (Mahadevaiah *et al.*, 1976) and the red pepper owes its intense red colour to around 40 carotenoid pigments synthesized massively during ripening. Noteworthy among these carotenoid pigments are capsanthin, capsorubin and capsanthin 5, 6 epoxide, which are almost exclusive to the genus *Capsicum* (Davies *et al.*, 1970). With a growing food safety concern against artificial colouring agents in food industries, chillies with high colour value, therefore, appear to be a very promising deal. The estimated carotenoid world market for the year 2003 was about \$1 billion and is increasing at an annual rate of about 7 per cent. Carotenoids have received increased attention in recent years as a potential nutraceutical component due to their powerful antioxidant function (Matsufuji *et al.*, 1998).

Carotenoids are able to prevent degenerative aging diseases, lipid peroxidation and formation of plaque in arteries, thereby helping to prevent atherosclerosis and coronary disease. Carotenoids have also been demonstrated to function effectively in boosting the immune system against human cancer diseases, as well as having an immuno modulating effect by enhancing cell to cell communication and antibody production. They are also gaining popularity in aquaculture by virtue of their use as feed additives. Chillies are valued as much for pungency as they are valued for colour. The active principle of pungency in chillies is capsaicin, which is an amide derivative of vanillylamine and 8-methyl-non-trans-6 enoic acid (Bernal *et al.*, 1993). High pungency chillies are preferred in the manufacture of pure capsaicin or in the preparation of pharmaceuticals like pain balms. Value addition in the spice sector has achieved commendable position in areas of exports. Oleoresins are one such value added products that are becoming increasingly important in the flavouring field. They are one of the major

ingredients in encapsulated flavours and the so called “soluble spices”. These later products are being used in ever increasing volume in the pickling trade, baking trade and meat product industry (Berke and Shieh, 2001).

Dried chilli and chilli powder are spices used as flavorings or condiments and are prepared from ripe chilli (*Capsicum* spp.). The most important quality characteristics in chilli are the colour and pungency. The red colour of chilli is mainly due to carotenoid pigments (Howard *et al.*,2000; Topuz and Ozdemir, 2007) and its pungency results from the capsaicinoids synthesized and accumulated in the epidermal tissue of the chilli placenta (Iwai *et al.*,1979; Suzuki *et al.*,1980). Some steps used in the processing of dried fruit and vegetables include blanching and drying during preparation; drying especially causes a major loss of colour and texture quality of the final product (Vega *et al.*,2008). To improve the quality of dried chilli, industrial dryers are used to decrease the drying time and provide uniform and hygienic processing conditions.

However, drying chilli with high temperatures leads to the loss of volatile compounds, nutrients and colour (Kaleemullah and Kailappan, 2006; Di Scala and Crapiste, 2008). In general, browning in dehydrated vegetable products is a major problem found in the food industry resulting from both enzymatic and non-enzymatic oxidation of phenolic compounds as well as from the Maillard reaction (Lyengar and McEvily, 1992). The browning reactions can be prevented by pretreatment methods, such as blanching and chemical treatment (Sigge *et al.*, 2001).

The quality of dried chilli is assessed by a number of different parameters such as colour, hotness, ascorbic acid content and volatile flavour compounds (Henderson, 1992; Ruth *et al.*, 2003; Jiang and Kubota, 2004; Kim *et al.*, 2006; Wang, *et al.*, 2009 and Yaldiz *et al.*, 2010). Traditionally, dried chilli is obtained by sun drying (SD) (Condori *et al.*, 2001). It takes about 7-20 days (depending on the weather conditions) to reduce the moisture content to 10-15 per cent (Oberoi *et al.*, 2005). Since dried chilli is susceptible to fungal proliferation, this process

creates favorable conditions for mycotoxin contamination (Bircan, 2005). To prevent fungal proliferation, different drying methods have been employed in the processing of dried chilli.

Currently, hot air drying (HD) is popular for drying chilli due to a relatively short drying time, uniform heating and more hygienic characteristics. The temperature ranges from 45 to 70° C, and this reduces drying time to less than 20 hrs. This temperature range gives maximum colour values and minimizes the loss of volatile oils and discolouration (Díaz-Maroto *et al.*, 2003; Ibrahim *et al.*, 1997; Berke and Shieh, 2001). However, freeze drying (FD) is the best method of water removal as it gives a final product of the highest quality without heat compared to other methods of food drying (Irzyniec *et al.*, 1995). It has been found that this is the most suitable drying method for maintaining the colour quality of dried chilli (Park and Kim, 2007). However, the flavour formation may not meet the requirement of the consumers. Therefore focus on the effects of drying methods on the quality, hotness and volatile flavour characteristic of dried chilli is a must. The literature related to present study has been reviewed as under:

2.1 Physico chemical observations of fresh chillies

2.1.1 Length (cm)

Cultivar Jwala recorded the highest value of fruit length 108 mm, followed by cultivar PC-1 of 99 mm (Garg, 2009). Singh *et al.* (2003) evaluated chilli genotypes for quality components. They observed that the fruit length varied significantly among various genotypes. Cultivar KDCS-810 recorded a fruit length of 84 mm. However the other cultivars LCA-235 and PC-1 recorded the fruit length of 75 and 82 mm respectively.

2.1.2 Breadth (cm)

Garg (2009) studied the physical parameters of some cultivars (KDCS-810 and LCA-235) of chillies wherein cultivar KDCS-810 observed a maximum breadth of 8.00 mm and cultivar Jwala a minimum of 6.9 mm.

2.1.3 Fruit weight (g)

While studying the physical parameters of some cultivars of chillies Garg (2009) reported that cv. Jwala recorded a 100 pod weight of 78 g and cv. PC-1 of 66.2 g. Singh *et al.*(2003) observed that LCA-235 had highest 100-pod weight of 65.7g whereas, cv. KDSC-810 recorded 100 pod weight of 51.80 g.

2.1.4 Seed (%)

A comparative study was done in 4 cultivars (Jwala, PC-1, KDSC-810 and LCA-235). The seed per cent in the cv. KDSC-810 recorded a highest of 46.7 per cent seed, followed by cv. Jwala of 42.1 per cent. However cv. PC-1 and LCA-235 recorded 40.5 and 39.0 per cent seed respectively (Garg, 2009).

2.1.5 Moisture (%)

Toontom *et al.*(2012) reported that initial average moisture content and water activity of fresh chilli were 85.15 per cent and 0.99 respectively in Chee fah chilli (*Capsicum annum* Linn. var. *accuminatum*Fingarh).

Nutritional composition of red bell pepper was reported by Famurewaet *al.* (2006). They observed 74 per cent moisture and 2.3 g fat in fresh chillies. Ajaykumaret *al.* (2012) reported chemical analysis of fresh chillies var. Tejas which showed 89 per cent moisture.

2.1.6 Ascorbic acid (%)

Ajaykumaret *al.* (2012) reported chemical analysis of fresh chillies var. Tejas which showed 29.33 mg/100g ascorbic acid. The fresh chillies recorded an ascorbic acid content of 53.19 mg/100g (Toontom *et al.*, 2012).

Seventeen fresh chilli varieties were evaluated for physico chemical attributes by Ananthiet *al.* (2004), amongst which variety PusaJwala had highest ascorbic acid content of 290.33 mg/100g. However Wiriyaet *al.* (2009) reported that fresh chillis contained 344.32 mg/100 g ascorbic acid.

Aniel and Sape (2009) reported the ascorbic acid content of chilli at five ripening stages viz. (M1, M2, M3, M4 and M5) from seventeen cultivars of *Capsicum annum*L and one cultivar of *Capsicum frutescens*L. Among eighteen genotypes the *C. annum*var. IC: 119262 (CA2) showed higher ascorbic acid content (mg/100g FW i.e., 208.0±0.68 (M1), 231.0±0.66 (M2), 280.0±0.31 (M3), 253.0±0.34 (M4) and 173.7±0.27 (M5). The study revealed that the gradual increase in ascorbic acid content from green to red and subsequently declined in the lateral stages (red partially dried and red fully dried fruits). The variability of ascorbic acid content in the genotypes suggests that these selected genotypes may be useful as parents in hybridization programs to produce fruits with good nutritional values.

2.1.7 Capsaicin content (%)

Sanatombi and Sharma (2008) reported that the cultivar ‘Umorok’ had the highest capsaicin content (2.06%), and was also the most pungent with 329.100 SHU (scoville heat unit) while the cultivar ‘Haomorok’ had the least capsaicin content (0.17%) with a corresponding pungency of 26.000 SHU (scoville heat unit).

Jyothiet *al.* (2008) reported the capsiacin per cent of 21 cultivars of fresh chilli amongst which cultivar BS-35 had highest value of 1.47 per cent and cultivar AKC 89/38 had lowest value of 0.16 per cent.

2.1.8 Capsanthin (%)/ASTA (extractable colour)

ASTA values in 2 cultivars of chiili were studied by Aleksandra and Biserka (2004) where cultivar Star Pazora had higher value of 225.95 ASTA units and cultivar Djala 206.73 ASTA units.

Anonymous (2005) studied ASTA values for 5 chilli types wherein type Guntur Sanna recorded an ASTA value of 32.11; Tomato Chilli-125.26; Birds Eye chilli- 41.7; Rymnad Mundu-32.95. However Byadagi chilli recoded highest

ASTA value of 156.9. ASTA colour value showed a range of 112±12 to 127±6 in paprika samples with different harvest dates (Naima *et al.*, 2013)

2.1.9 Reducing sugar (%)

Reducing sugar of 6.51 mg/g in fresh chilli was reported by Jyothiet *al.* (2008). Kyung *et al.* (2012) studied the reducing sugar in 12 different cultivars of red chillis where they observed a range of 5.60-9.43 per cent (db).

2.1.10 Colour values (L*, a*, b*)

Changes in surface colour of chilli was recorded by Aleksandra and Biserka (2004) where the L*, a*, b* values were 39.46, 23.08 and 27.97 in cultivar Djala and 36.87, 25.78, 31.91 in cultivar Stara Pazova. L*, a*, b* values were studied by Naima *et al.* (2013) in paprika where L* varied from 23.98-27.27.79; a* from 27.16-29.50 and b* from 29.52-34.00.

2.2 Drying methods of chillies

Shivareet *al.* (1981) established five sets of experiments for drying of chillies with and without stalk at 50 or 52°C. They found that all the drying took place at falling rate period and drying temperature 50°C is appropriate as it involves lower energy consumption resulting in lower drying costs without loss of capsaicin content of chilli.

Shrivastava *et al.* (1990) designed a low cost solar cabinet type drier with overall dimensions of (1450 x 1463 x 805 mm) to dry 25 kg of chillies. The comparative studies on the effect of bed thickness showed that drying time increases with increase in bed thickness. Drying time was found to be half of the sun drying.

Zhan (1996) investigated the variations in carotenoid pigments in chilli during drying. Ripe fruits were dried at 35°C and sampled at various phases. Carotenoid pigments in ground meals were determined by TLC. Results showed that carotenoid pigments increased with drying time from 0-84 hr, but decreased

thereafter. Total carotenoid pigment contents at the end of drying, when meals had a moisture content of 4 per cent, was 19-26 per cent higher than at the beginning of drying. When drying was performed in light for 84 hr and in the dark between 85-324 hr, meals had carotenoid pigment contents 50 per cent higher than at the beginning of drying.

Hossain and Bala (2002) studied the thin layer drying characteristics for green chilli under both overflow-underflow and through flow conditions with air temperature 40-65°C, RH 10-60 per cent and air velocity 0.10-1.0 m/s. Single exponential and Page's model were used to determine the thin layer drying characteristics for green chilli. Both equations fitted well to the experimental data, however, the Page's equation described the thin layer drying of chilli most closely. Parameters of Page's and single exponential equations were expressed as functions of drying air temperature, RH and air velocity.

Weerachai *et al.* (2002) studied the drying of chilli in a combination of microwave- vacuum rotary drum dryer. This technique was designed to combine the advantages of vacuum drying, used for drying sensitive material with evenly dispersed microwave energy in rotary drum. The drying kinetics and the specific energy consumption at particular product moisture contents were measured experimentally. Effects of vacuum pressure (60, 160, 260 mmHg) inside the chamber and rotational speed of the drum (10, 20 and 25 rpm) were also determined. Higher drying vacuum pressure resulted in the lower drying times and the optimum operating speed to remove moisture from chillies was 20 rpm. In general, drying rates increased markedly when the process started at a high moisture content, drying rate was then consistent until the moisture content was approx. 0.75 per cent dry basis, when it declined sharply. Varying drum speed and vacuum pressure did not affect specific energy consumption when the moisture content of the chillies was high and vice versa.

Effect of mechanical drying at temperatures 45, 55, 65 °C on quality of chilli was studied by Sadhna and Bharti (2005) wherein, variety Punjab Lal recorded the best quality when dried at 55 °C.

Joy *et al.* (2001) made studies on solar tunnel drying of red chillies to improve the quality of dried products. Results of quality analysis of both tunnel dried chilli samples and those dried by conventional open air sun drying from same samples indicated a considerable reduction in drying time in tunnel dried samples, which showed improved texture and hygienic quality over conventional air dried samples. Chillies dried in solar tunnel dryer were hygienic and showed high quality over commercially available chillies. In solar tunnel dried samples, drying time was highly reduced when compared to the commercial samples (Lee *et al.*,2004).

A study was conducted by Mangaraj *et al.* (2001) to evaluate the performance of different drying methods, namely open sun drying on cemented floor, green house-type solar dryer (with natural ventilation system), solar cabinet drying (natural convection type) and mechanical drying for both unpunched and punched fresh red chillies of “Jwala” variety. It was observed that the time taken and overall quality for drying was minimum for mechanical drying followed by solar cabinet drying, green house type solar drying and open sun drying.

Wiriyat *et al.* (2009) while studying drying air temperatures of dried chilli reported best colour attributes with two stage temperatures of 70 and 50°C using sodium metabisulphite combined with calcium chloride. Arora and Bharti (2005) reported that the variety Punjab Lal was found best in quality when dried at 55 °C in comparison to “Punjab Surkh, Punjab Guchheddar, CH-1”. A study conducted by Satyanarayana and Vengaih (2010) reported that the drying temperature of 55°C was best for preventing the pigment loss during drying and drying time required to reduce moisture from 292.5 per cent to 9.6 per cent (DB) varied considerably depending upon whether chilli pods were thin pericarp type varieties

or thick pericarp type hybrids. The hybrids took about 40 h to dry where as the varieties took about 24 h.

2.3 Effect of pre-treatments and drying methods on drying behaviour of chilli

Ahmad and Shivare (2001) studied the effect of pretreatments on drying characteristics and colour of dehydrated green chillies. Pretreatments investigated were blanching (95°C for 5 min) followed by dipping for 15 min at room temperature in either cold water (control), 1000 ppm SO₂ solution, 1 per cent lye solution containing copper sulphate and magnesium sulphate each at 500 ppm and 1 per cent lye solution containing 0.25 per cent magnesium carbonate. All pretreatments increased drying rate, while blanched chillies dipped in 1 per cent lye solution containing 0.25 per cent magnesium carbonate retained maximum colour in terms of Hunter value. Drying kinetics studies revealed that drying took place under the falling rate period. Page's model fitted well to drying behaviour data

Gupta *et al.* (2002) studied the drying characteristics of red chilli. They investigated the effects of pretreatments (potassium carbonate, gum acacia, ground nut oil containing 1000 ppm TBHQ and blanching (control) on drying kinetics and product quality of red chillies (var. Sathi). Pretreated chillies were dried in a tray drier at 55, 60, 65 or 70°C. Inactivation of peroxidase was achieved by blanching chillies at 90 °C for 3 min. Physical appearance of dried chilli was found to be best when the blanched samples were soaked in gum acacia solution (0.2 per cent m/v) for 15 min at room temperature. The falling rate period of drying came with an activation energy of 41.95 and 41.06 kJ/mol for blanched and gum treated chillies respectively. With increase in drying air temperature, total pigment content decreased while as non-enzymatic browning increased.

Kumari *et al.* (2003) studied the effect of different chemical treatments and drying methods on the physical properties of chillies. Chillies were treated with calcium carbonate, potassium sulphate and potassium nitrate and dried by open

yard sun drying, tray drying or solar drying, pod length, time taken to reach a safe moisture content (8-10%) and percent of damage were measured. No marked differences in pod length due to different drying methods, chemicals and their interaction were observed. Visual differences due to drying methods were seen while tray drying was most effective method and caused least wrinkles on pods after drying. Pod colour after drying was bright red for tray drying, red for solar drying and light red for open yard sun drying methods. Time to reach a safe moisture content was influenced by drying method where in tray drying was superior and resulted in lowest percentage on damaged pods.

Jasim and Shivare (2001) studied the effect of pre treatments on drying characteristics and colour of dehydrated green chillies and reported blanching in hot water at 95°C for 5 min followed by dipping chillies in solution containing 1 per cent lye and 0.25 per cent magnesium carbonate at room temperature for 15 min and drying at 60°C resulted in retaining maximum green colour in the dried product. Gupta *et al.* (2002) reported the inactivation of peroxidase enzyme and best quality by blanching chillies at 90 °C for 3 minutes in hot water followed by soaking in gum acacia (0.2 per cent m.v) for 15 minutes at room temperature. Eleyinmiet *al.* (2002) reported the samples soaked in sodium chloride and potassium metabisulphite gave better mineral retention values than blanched samples.

2.4 Physico-chemical properties of dried whole chilli and chilli powder

2.4.1 Moisture (%)

Kwanhathaiet *al.* (2012) studied the effect of sulphur dioxide (SO₂) on chilli Jinda variety (*Capsicum annum* L.) after soaking fresh pods in 200, 1000 and 2000 mg/kg sodium metabisulfite (Na₂S₂O₅) for 30, 60 and 120 min. They reported that the dried chillies had a moisture (%) range of 7.3- 8 per cent and water activity (a_w) range of 0.31-0.34. However in chilli powder, after storing the samples at 40°C in polypropylene bags for 30 days, values for the moisture

content and water activity increased significantly to about 9.2-9.4 per cent and 0.45-0.50 respectively.

Pura *et al.* (2001) while studying the packaging and storage studies of chillies revealed that the moisture content of 14 and 11.2 per cent were critical for facilitating mould growth in them. But initial moisture contents of 10.45 per cent at 64 per cent RH and 9.60 per cent at 57 per cent RH were found critical for storage of these varieties respectively. Under tropical conditions 300 gauge high density polyethylene (HDPE) films were suitable for packaging Guntur and Byadgi whole chillies in unit packs of 250 g.

Ayhan *et al.* (2009) reported the moisture content (%wb) of paprika which ranged 4.64 to 5.02 per cent in freeze dried and oven dried paprika. However the water activity ranged from 0.328 to 0.329 respectively.

A comparative study was conducted to evaluate two drying methods with respect to temperature and time combinations. Freshly harvested Byadgi chilli fruits were treated with dipsol, potassium nitrate and citric acid and dried in solar tunnel dryer and open yard drying. It took 39 hours to bring down the moisture content of chillies from 339.14 per cent (db) to 10.00 per cent (db) in solar tunnel drying as against 57 hour under open yard drying (Manjula *et al.*, 2011).

Wiriy *et al.* (2009) studied lab scale tray dryer in order to reduce the quality loss caused by sun drying. Different drying temperature from 50-70°C were used to compare with sun drying. It was observed that the moisture content of chilli obtained from the different conditions were 9.7-11.2 per cent while as water activities were 0.42-0.48.

2.4.2 Ascorbic Acid (%)

Daood *et al.* (1996) reported a dramatic decrease in ascorbic acid contents of red pepper during drying. However they also observed that the natural drying was more destructive than forced air drying. Howard *et al.* (1994) reported that 75

per cent of ascorbic acid in red pepper was lost during drying, with the final content of ascorbic acid being in the range of 12.0 mg/100 g.

Markus *et al.* (1999) reported that the ascorbic acid in the Hungarian red pepper stored at 0°C was in a range of 3.7 to 13.9 mg/100g. Vega *et al.* (2008) studied the effect of air temperature on quality of dried red bell pepper on 4 inlet temperature 50, 60, 70, 80°C and pretreatments NaCl, CaCl₂, Na₂S₂O₅ and reported that the air drying temperature had a detrimental effect on the retention of ascorbic acid as heated air inherently exposes the product to oxidation hence reducing their ascorbic acid.

The ascorbic acid (mg/100g) of variety Tejas of dried chilli pretreated with ascorbic acid and NaCl was reported by Ajaykumare *et al.* (2012). Pretreatment with ascorbic acid and drying temperature 70°C gave the highest ascorbic acid of 51.56 mg/100g. However pretreatments blanching and drying temperature 60°C showed the lowest ascorbic acid of 30.40 mg/100g. Toontomet *et al.* (2012) reported that the ascorbic acid of all dried chilli varied between 14.21 and 51.55 mg/100g.

Wiriyat *et al.* (2009) reported a significant effect of methods of drying on ascorbic content of dried chillies. The highest ascorbic acid of 49.31 mg/100g was reported in chilli dried at 50 °C while as the lowest of 35.76 mg/100g in sun dried chillies. Pal *et al.* (2008) while studying heat pump drying of green sweet pepper at 30, 35 and 40 °C and hot air dryer at 45°C with RH ranging from 19-55 per cent reported the significant retention of total chlorophyll content and ascorbic acid content in heat pump dried samples. The quality parameter showed a decline in trend with increase in drying air temperature from 30-45°C.

Famurewa *et al.* (2006) studied dehydration of osmosised red bell pepper. The osmosised sample was finally subjected to freeze drying, oven drying and solar drying. After drying, the proximate composition, vitamin C content and water absorption capacity (WAC) of the samples were analysed. The vitamin C and WAC contents were 150 mg/100 g and 100 per cent v/w, 125 mg/100 g and

350 per cent v/w, 100 mg/100 g and 250 per cent v/w, 125 mg/100 g and 300 per cent v/w and 200 mg/100 g and 50 per cent v/w for osmosised raw, freeze dried, solar dried, oven dried and raw pepper samples respectively. These results indicated that freeze drying method was the best method that resulted in the less reduction vitamin C content of the pepper after drying and had the highest water absorption capacity.

2.4.3 Capsaicin content (%)

Wang *et al.* (2009) while studying the capsaicinoids in chilli pepper powder as affected by heating and storage methods reported that low temperature storage improved retention of capsaicinoids and vacuum packaging provided extra benefit. However at temperatures >190 °C, capsaicin and dihydro-capsaicin degraded rapidly.

While studying the drying kinetics of red chillies (Pb-Lal, Pb-Guchheddar, Pb-Surkh and CH-1) Arora *et al.* (2006) reported that Pb-Lal has highest capsaisin content of 532.08 µg. The decrease in pungency of the chillies due to higher temperature of drying was observed by Kaleemullah and Kailappan (2006). The average capsaicin content of chillies decreased from 0.60 to 0.34 per cent as the air drying temperature increased from 50-65°C.

Toontomet *et al.* (2012) reported the capsaicin content and hotness of dried chilli from freeze drying, hot air drying and sundrying. They observed that capsaicin content and hotness from all drying methods were higher than fresh chilli samples. The lower capsaicin content in fresh chilli may be due to peroxidase enzyme by catalytic activity.

The capsiaicin content of dried Indian chillies reported by Prasanth and Ponnuswami (2008) in Indian chillies ranged from 0.17-0.226 per cent. The effect of solar tunnel drying on the quality of dried chillis was reported by Joy *et al.* (2001). The capsaicin per cent by weight was 0.20 per cent. Lee *et al.* (2004)

reported capsaicin content of Korean red pepper powder ranged from 28.18 to 32.35 mg/100 g.

2.4.4 Capsanthin (%)/ASTA (extractable colour)

Sunaet *al.* (2006) reported the ASTA colour values for Modified Method (MM) and Conventional Method (CM) of drying were 114.0 ± 0.69 and 107.4 ± 1.25 respectively. ASTA colour values between MM and CM made little difference although the pigment in drying by the MM was slightly more conservative by than in CM.

Kimet *al.* (2004) attributed the ASTA colour value to carotenoids such as capsanthin, capsorubin and β -carotene. Effect of selected pretreatments on drying characteristic and colour of chilli was investigated by Jasim and Shivare (2001). Chillies pretreated with blanching using 1 per cent lye solution and 0.25 per cent $MgSO_4$ dip showed maximum colour retention.

To improve the product quality/microwave assisted vacuum drying was studied by Sankrit and Nantawan (2009). Red chilli pretreated with soaking in 0.5 per cent citric acid solution and then drying at 1120W microwave power and 160 mmHg had significant effect on the colour and pigment retention.

Ljuboet *al.* (2007) observed the highest extractable colour of 96.75 in pepper powder at 0 days of storage. However sterilization resulted in the deterioration of the colour as a consequence the measured ASTA value of 95.06 per cent.

2.4.5 Reducing sugars (%)

The reducing sugar level of dried red chillis were between 4.99- 5.26 mg/100g. However decrease in reducing sugar resulting in the browning compounds due to non-enzymatic browning reaction between reducing sugar and amino acid (Wiriya *et al.*, 2009).

A comparative study of variety (Tejas and NP-46) and temperature (60°C and 70°C) was observed by Ajaykumaret al. (2012). The variety NP-46 dried at 70°C and pretreatments NaMS+CaCl₂ observed the highest reducing sugar (mg/g) of 298 while as variety Tejas pretreated with blanching and dried at 60°C recommended the lowest reducing sugar of 41mg/g.

2.4.6 Colour value (L*, a*, b*)

The colourimetric values of red pepper dried by MM and CM were L*=38.09, a*= 36.78 and b*= 30.71 and L*=34.62, a*= 29.61 and b*= 26.26 respectively. The Modified Method (MM) of drying showed higher b values of lightness, redness and yellowness than Conventional Method (CM) of drying (Suna et al.,2006).

Ramakrishnan and Francis (1973) showed that a major colour change in heated paprika was due to large increase in the content of brown pigments. Park and Lee (1975) reported that the brown pigment dried in red peppers was due to high levels of reducing sugars and amino acid in red peppers.

Low drying rate gave superior colour quality and hence high degree of dehydration reached the rheology of the product and the high concentration of pigment give paprika with a dark earthy appearance (Minguez et al.,1994).

L*, a*, b* values for surface colour changes in ground pepper during storage were reported by Ljubo et al. (2007). The pepper stored in ambient conditions changed its lightness from initial 34.84 to 37.58. Kwanhathai et al. (2012) studied the quality colour parameters of dried chilli powder treated by metabisulphite. They reported the L*a*b* values of dried chilli significantly increased with increasing Na₂S₂O₅ concentration. The dried chilli obtained from soaking in 2000mg/kg Na₂S₂O₅ concentration for all soaking time (30-120 min) exhibited L* a* b* values of 28.7, 22.8 and 12.5 respectively.

Ibrahim and Mehmet (2002) reported the L*a*b* values of chillies dried at 50 and 60°C. The chillies dried at 50°C showed an L*a*b* of 24.70, 15.42 and 5.89 and at 60 °C and L*a*b* of 22.92, 11.73 and 5.07 respectively.

2.4.7 Non-Enzymatic Browning (NEB)

Absorbance of browning pigments were 0.16 and 0.26 in red pepper samples dried by Modified Method (MM) and Conventional Method (CM) of drying (Suna *et al.*,2006).

The browning pigments in the non-treated and pre-treated samples were reported by Vega *et al.* (2008). They observed that pretreated samples showed lower browning pigments (0.011±0.006Abs/g initial dm) than the non-treated samples (0.038 to 0.063 Abs/g initial dm).

Hayamet *al.* (1997) studied the oven drying of paprika samples at temperature of 40, 60, 80°C and reported that upon drying the browning compounds were formed at minimum level of 28.82 per cent upon drying the treated samples at 40°Cfor 130 hours, whereas, the same results were obtained for drying at 60 and 80°C for 24-36 hours and less than 6 hours respectively. Paprika samples dried at 80°C the browning compounds increased to 91.22 per cent at 13 hours of drying.

2.5 Anti oxidant activity of dried chillies

There are growing evidences suggesting that antioxidants may maintain health and prevent many chronic diseases, such as certain cancers, cardiovascular diseases and other aging-related diseases (Thompson, 1994). Antioxidants may suppress the formation of free radicals, quench the existing radicals and reduce the availability of oxygen in biological system to prevent the oxidative damage of proteins, DNA and lipids in human body (Fairfield *et al.*, 2002).

Capsicum cultivars have been identified as potential solanaceous crop with high antioxidant activity (Howard *et al.*, 2000). Hot pepper is an important vegetable crop both economically and nutritionally because these are excellent

sources of natural colours and antioxidant compounds. Intake of these compounds in food is an important health protecting factor. They are also helpful in prevention of widespread diseases. A wide spectrum of antioxidant vitamins, carotenoids, capsaicinoids and phenolic compounds are present in hot pepper fruits (Ou *et al.*, 2002). The intake of these compounds in food is an important health-protecting factor by prevention of widespread human diseases.

As consumption continues to increase, hot peppers could provide important amounts of nutritional antioxidants to the human diet. Levels of these antioxidants can vary with genotype, stage of harvest/maturity and plant part consumed as well as storage and processing conditions (Marin *et al.*, 2004) but maturation affects synthesis of these compounds which influence hot pepper quality e.g. differences in hot pepper colour, shape and capsaicin level changes continuously during maturation. Important nutrients like ascorbic acid and provitamin A increased from green stage to the red stage (Sidonia *et al.*, 2005).

Sunaet *al.* (2006) reported that the anti oxidant activity and ascorbic acid contents of red pepper were significantly affected by drying conditions. The AAEAC values for red pepper dried by the modified methods were 34.87 ± 1.18 and 28.05 ± 1.23 mg/g in the ABTS [(C 2,2-azino-bis (3 ethyl benzthiazoline-6-sulfonic acid)] and DPPH [(2,2- diphenyl-1- picrylhydrazyl)] radical scavenging assays respectively. While those of red pepper dried by the conventional drying methods were 10.22 ± 0.16 and 9.43 ± 0.22 mg/g respectively.

2.6 Storage

Krishnamurthy and Natarajan (1973) studied the storage of whole chillies in cans and found that samples with moisture content of 11.0-12.9 per cent retained a high colour than samples with moisture content below 9 per cent. However samples stored at 11-12 per cent moisture content turned black while those at below 7 per cent turned pale in colour

Mahadevaiah *et al.* (1976) conducted studies on packaging and storage of

dried Guntur variety of chillies in flexible consumer packages and revealed that (i) a moisture content higher than 15 per cent is critical with respect of mould growth; (ii) the discolouration of the red pigments of chillies was greatly influenced by moisture and temperature and (iii) under tropical conditions 200 gauge low and high density polyethylene films were suitable for packaging of whole chillis in units of 250 g. The samples exposed to sunlight were bleached and showed dull appearance in all types of packages.

Puraet *al.* (2001) made studies on storage of commercial varieties of Indian chillies. Capsaicin content decreased with storage. Sorption isotherm studies indicated that initial moisture content of 10.45 per cent at 64 per cent RH for Guntur variety of chilli was sufficient for safe storage of packaged products under ambient conditions. Colour of the chilli also darkened due to formation of non-enzymatic browning.

2.7 Sorption isotherm

Moisture sorption isotherm studies were done by Figen and Mustafa (2001) wherein they reported that the sorption isotherms give the characteristic S-shaped curve, typical of the many sorption isotherms give the characteristic S shaped curve typical of the many sorption isotherms of the foods. The sorption isotherms also show that the adsorption and desorption isotherm exhibited hysteresis in which the equilibrium moisture content was higher in particular water activity for desorption curve than for adsorption. The hysteresis was significant for water activity >0.5 at 30 °C while it was insignificant for higher temperature especially at 60 °C.

Kaleemullah and Kailappan (2004) reported that the adsorption and desorption isotherms exhibited the phenomenon of hysteresis in which equilibrium moisture content was higher at a particular ERH for the desorption curve than for adsorption. Furthermore they observed the magnitude of the hysteresis for isotherms at 25°C exceeds that at 45°C. The hysteresis values

increased gradually nearly upto 0.60-0.65 ERH and afterwards the values increased sharply upto 0.74-0.76 ERH. The hysteresis values starting declining after 0.74-0.76 ERH i.e. with increase in temperature the hysteresis magnitude decreased.

Pal *et al.* (2008) studied the thin layer drying experiments under controlled conditions for green sweet pepper in heat pump dryer at 30, 35 and 40 °C and hot air dryer at 45 °C with RH ranging from 19-55 per cent. As the temperature increased, the drying curve exhibited a steeper slope thus exhibiting an increase in drying rate. Drying of green sweet pepper took place mainly under the Falling rate period.

2.8 Drying kinetics

Vega *et al.* (2007) studied the drying kinetics of red bell pepper modeled at different temperatures (50, 60, 70 and 80°C using an air velocity of 2.5 m/s. The effective moisture diffusivity was between 3.2×10^{-9} and $11.2 \times 10^{-9} \text{m}^2/\text{s}$ within the temperature range studied. The effect of temperature on the diffusivity was described by Arrhenius equation with an activation energy of 39.70kJ/mol. The Newton, Hunderson-Pabis, Page and Page modified models were applied to the experimentally obtained moisture data.

The thin layer drying behavior of red pepper slices was investigated by Akpinaret *al.* (2003) in a convective dryer. Drying experiments were conducted at inlet temperatures of drying air of 55, 60 and 70 °C and at a drying air velocity of 1.5 m/s. According to the results, an approximation of diffusion model could satisfactorily describe the drying curve of red peppers with a co-relation coefficient (r) of 0.9987.

Kaleemullah and Kailappan (2006) reported that the effective moisture diffusivity (D_{eff}) of chillies increased from 3.78×10^{-9} to $7.10 \times 10^{-9} \text{m}^2/\text{s}$. As the drying air temperature of thin layer dryer increased from 50 to 65 °C. The activation energy of diffusion was calculated as 37.76 kJ/mol.

Karina and Guillermo (2008) reported that the effective moisture diffusivity ranged from 5.01 to $8.32 \times 10^{-10} \text{ m}^2/\text{s}$ with an activation energy of 23.35 kJ/mol. The rate constants increased with temperature and product moisture content. Average activation energies for carotenoids and vitamin C degradation were 50.1 and 26.9 kJ/mol respectively.

Hossain and Bala (2002) observed that the single exponential equation and the Page equation were used to determine the thin layer drying characteristic for green chillies. Both the equation fitted well to the experimental data. The Page equation was found to describe the thin layer drying of chilli better than the single exponential equation.

Chapter – 3

MATERIALS AND METHODS

The present investigations entitled, “Effect of drying methods and packaging materials on storage stability and quality of chillies” was carried out in the Food Processing Laboratory of Division of Post Harvest Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during the year 2011-2012 and 2012-2013. The materials and methods applied are described under the following heads:

3.1 Raw material

3.1.1 Fresh chilli samples

Freshly harvested chillies variety (Kashmir Long-1) were procured from research field of the Division of Vegetable Science, SKUAST-K, Shalimar. The harvested chillies at red ripe stage were brought to Food Processing Laboratory, Division of Post Harvest Technology, SKUAST-Kashmir, Shalimar and were kept in shade for 1 hour to remove field heat. The bruised, diseased and damaged chillies were removed and sound ones were washed with tap water to remove adhered dirt.

3.1.2 Pre-treatment details

The chillies were pretreated with chemical dips and then divided in three equal lots replicated thrice to study the effect of sun, solar tunnel and mechanical drying at 45, 55, 65°C. Before drying chillies were subdivided into 500 g per treatment replicated thrice pretreated (Plate-1) using the following dips:

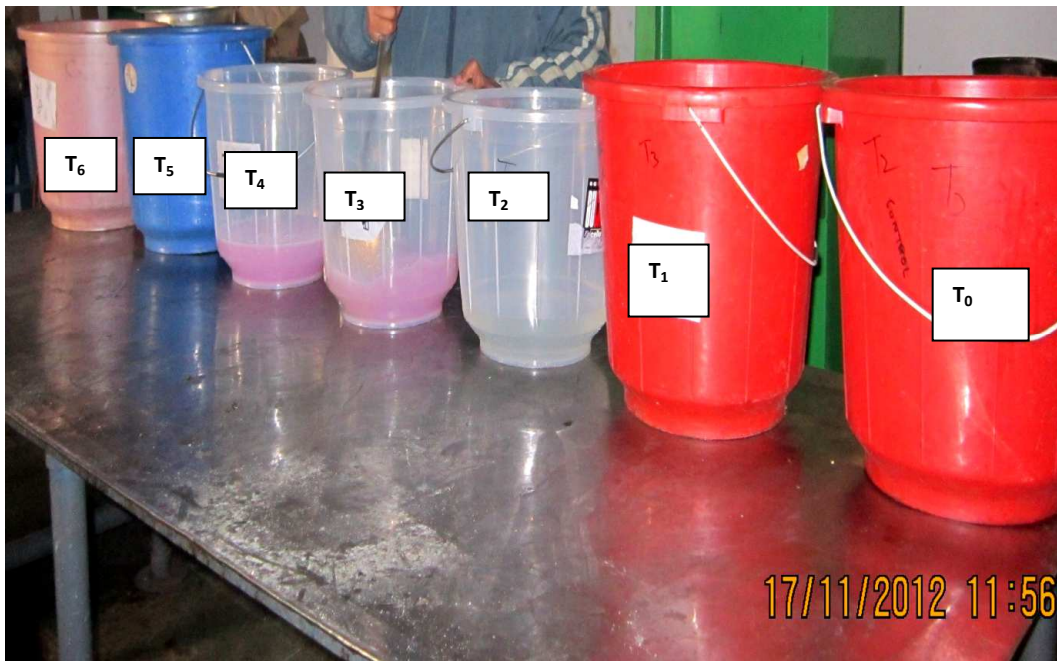


Plate-1: Sorting and pre treatment application of fresh chillies

No. of Pre-treatments : **8**

S. No.	Treatment details
(T ₀)	Control
(T ₁)	0.5% citric acid dip (20 min.)
(T ₂)	1% Potassium metabisulphite + 0.5% citric acid (20 min.)
(T ₃)	2% Potassium metabisulphite + 0.5% citric acid (20 min.)
(T ₄)	2.5% Potassium carbonate + 2% ethyl oleate (5 min.)
(T ₅)	5% Potassium carbonate + 2% ethyl oleate (5 min.)
(T ₆)	7.5% Potassium carbonate + 2% ethyl oleate (5 min.)
(T ₇)	2.5% Potassium carbonate + 1% ground nut oil+ 0.1% gum acacia +0.001% BHA per liter (15 min.)

3.2 Experiment No. 1: Effect of pre-treatments, drying methods and storage period on quality of whole chillies (Kashmir Long-1)

3.2.1 Drying methods:Two

Two drying methods(Plate-2) were used to dry the chillies namely:

S. No.	Method of drying
1	Sun drying
2	Solar tunnel drying

3.2.2 Sun drying

Triplicate samples (500 mg) of pretreated chilli with initial moisture content of 80.686 per cent were spread on aluminum trays (90 × 60 × 7.5cm) kept on black polyethylene and were placed under direct sunlight during day time between 9 am to 5 pm. Samples were given regular turnings to achieve uniform drying. Weight loss was recorded by weighing samples after hour on electronic



Plate-2 : Solar tunnel dryer schematic diagram

balance (Make Citizen). On each drying date the samples were collected in the evening and kept in perforated and closed polyethylene bags and spread out again on the following day. The process was repeated till the drying was achieved to predetermined moisture of about 10-11 per cent. The temperature and relative humidity was recorded during the entire period of drying by keeping the thermometer and thermo-hygrometers (Model 372000 AKTON) hanging. The chillies were later packed in re-sealable polythene bags for storage under ambient conditions ($27.87 \pm 2^\circ\text{C}$ temp) and samples were drawn at 0, 30, 60, 90, 120 days for further evaluation.

3.2.3 Solar tunnel drying

Preatedchillies were loaded on aluminum trays ($90 \times 60 \times 7.5\text{cm}$) as described for sun drying. The loaded trays were then put in a solar dryer which consisted of frame work of $\frac{3}{4}$ " G.I. pipes provided with 5 number of independent units joined together with nuts and bolts at selected points formed a tunnel like structure with a length of 450 cm, breadth of 300 cm and a height of 240 cm at the center (Plate-3 and Plate-4). The dryer was covered with an ultra-violet stabilized white polyethylene (800 gauge; 200 micron) and floor was covered with black polythene. The dryer was provided with a single door and ventilator holes in cross direction to facilitate the movement of air. The dryer had a capacity to accommodate 18-20 trays ($90 \times 60 \times 7.5\text{cm}$) in a single layer to facilitate movement drying operations. The chillies were loaded at the rate of 500gm/tray and dried to approx. 10-11 per cent moisture.

The temperature inside the dryer was recorded using thermometers hanging 90 cm above the tray height. Thermo-hygrometer (Model 372000 AKTON) was used to measure relative humidity inside the solar tunnel dryer during drying process. An average temperature of $44.04 \pm 2^\circ\text{C}$ temp and relative humidity of 25.48 percent was recorded inside the solar tunnel dryer. The chillies were later packed in re-sealable polythene bags for storage under ambient

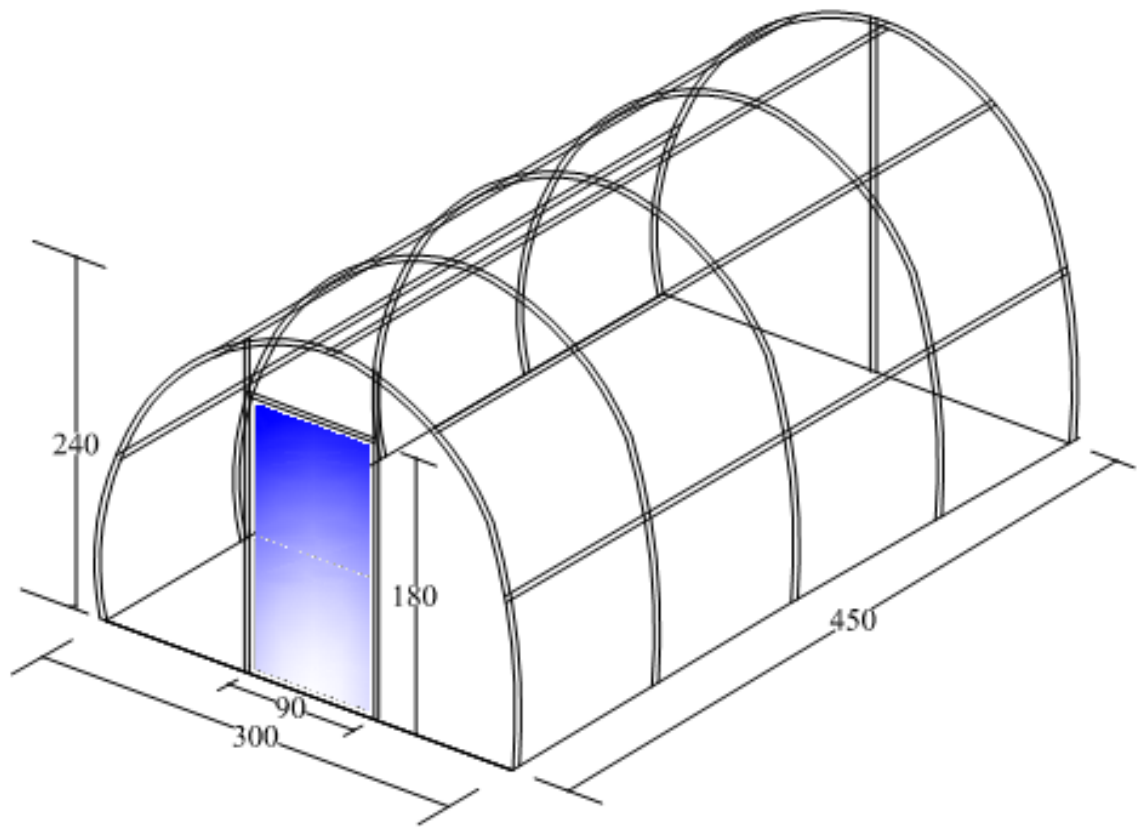


Plate-3 : Solar tunnel dryer schematic diagram



Plate-4 : Sun and solar drying of pre treated chillies

conditions ($27.87\pm 2^{\circ}\text{C}$ temp.) and samples were drawn at 0, 30, 60, 90, 120 days for further evaluation.

3.3 Experiment No. 2: Effect of pre-treatments mechanical drying temperatures and storage period on quality of chillies (Kashmir Long-1)

3.3.1 Drying temperature

Three drying temperatures were used for mechanical drying of chillies:

1. (D₁) : 45 °C
2. (D₂) : 55 °C
3. (D₃) : 65 °C

3.3.2 Mechanical drying

Mechanical drying of pretreated chillies was carried out in a cabinet tray dryer using hot air as drying medium. The dryer had the facility to regulate air temperature ($\pm 2^{\circ}\text{C}$). Three drying temperatures *viz.* 45, 55, 65 °C were selected to undertake the drying of chillies. Dryer was pre unloaded for 30 minutes to desired level of air velocity and temperature. 1.5 kg of chilli with predetermined moisture were spread in a single layer on the aluminum trays (75 x 45 x 6cm) and loaded in the dryer. Samples were regularly turned to ensure uniform drying. Weight loss was recorded by weighing samples after hourly intervals on electronic balance (Make Citizen). The drying was considered to be complete when the chillies attained the moisture content of 10-11 per cent. The chillies were later packed in re-sealable polythene bags for storage under ambient conditions $27.87\pm 2^{\circ}\text{C}$ temperature and samples were drawn at 0, 30, 60, 90, 120 days for further evaluation (Plate-5).



Plate-5 : Mechanical cabinet dryer

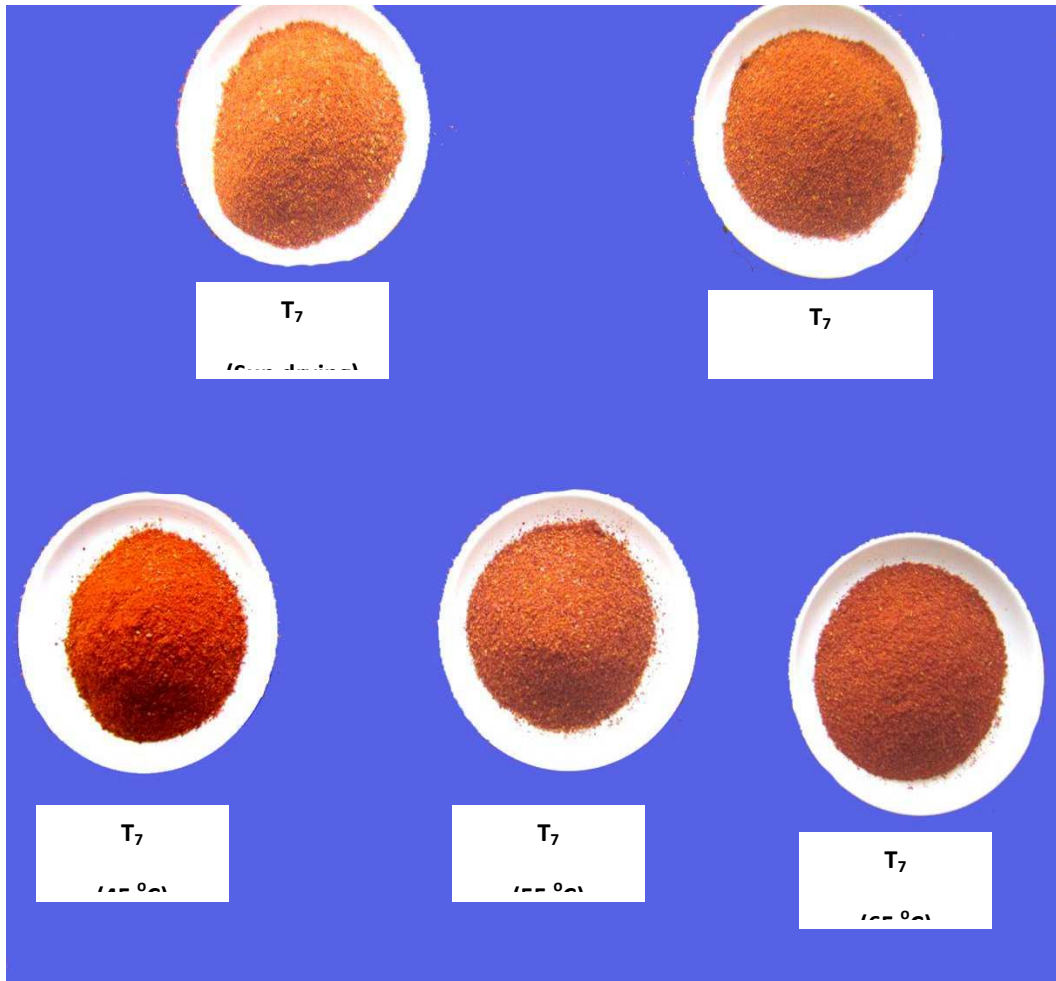


Plate-6 : Comparison of best pre-treatments in chilli powder (Kashmir Long -1)

3.4 Experiment No. 3: Effect of packaging materials and storage period on quality attributes of chilli powder (Plate-6)

- A. Sun drying and Solar drying was carried out using best pretreatments and the chillies after drying were powdered.
- B. Similarly best pre-treatment and best temperature were used for cabinet drying of chillies and chillies were powdered and packed in three packaging materials
 - 1. Metallised laminated polyster (MLP).
 - 2. Low Density Polyethylene (LDPE).
 - 3. Vacuum packaging (VP).

3.5 Sampling intervals: Five

The chillies dried by all the above three methods were analysed for various physico chemical observations at the following sampling intervals:

- | | | |
|----|-------------------|---------|
| 1. | (S ₀) | 0 Day |
| 2. | (S ₁) | 30 Day |
| 3. | (S ₂) | 60 Day |
| 4. | (S ₃) | 90 Day |
| 5. | (S ₄) | 120 Day |

3.6 Physical observations in fresh chillies

3.6.1 Physical observations

3.6.1.1 Length (cm)

The length of the fruits from twenty randomly selected samples in triplicate of each treatment was measured by vernier calliper. Average values were calculated and expressed in cm.

3.6.1.2 Breadth (cm)

The breadth of the fruits from twenty randomly selected samples in triplicate of each treatment was measured by vernier calliper at middle portion, base and apex of the fruit. Average values were calculated and expressed in cm.

3.6.1.3 Weight (g)

Fresh weight of chilli fruits from each treatment for 20 randomly samples in triplicate was recorded and average values were calculated and expressed in grams.

3.6.1.4 Seed (%)

Seed per cent was calculated by ratio of weight of dried seed and weight of dried whole chilli multiplied by 100:

$$\text{Seed (\%)} = \frac{\text{Weight of seed}}{\text{Weight of whole chilli}} \times 100$$

3.6.2 Chemical observations recorded in fresh, dried chillies and chilli powder (Plate-7 and Plate-8)

3.6.2.1 Moisture (%)

Moisture content was estimated by the method described by AOAC (1995). Weighed 5 g sample in triplicate were dried in hot air oven at $60^{\circ}\text{C} \pm 5^{\circ}\text{C}$ in pre-weighed dishes for 12 hour till constant weight. The dish with dried sample was transferred to a dessicator and cooled to room temperature. The dish was then weighed and moisture content in per cent was calculated from loss in weight.

3.6.2.2 Ascorbic acid (mg/100g)

Ascorbic acid was estimated by the method as described by Rangana (1986) using 2, 6-dichlorophenol indophenol dye. Dye factor was calculated by titrating 5 ml standard ascorbic acid plus 5 ml (3%) metaphosphoric acid against 2, 6-dichlorophenol indophenol till pink colour appeared and volume used was noted.

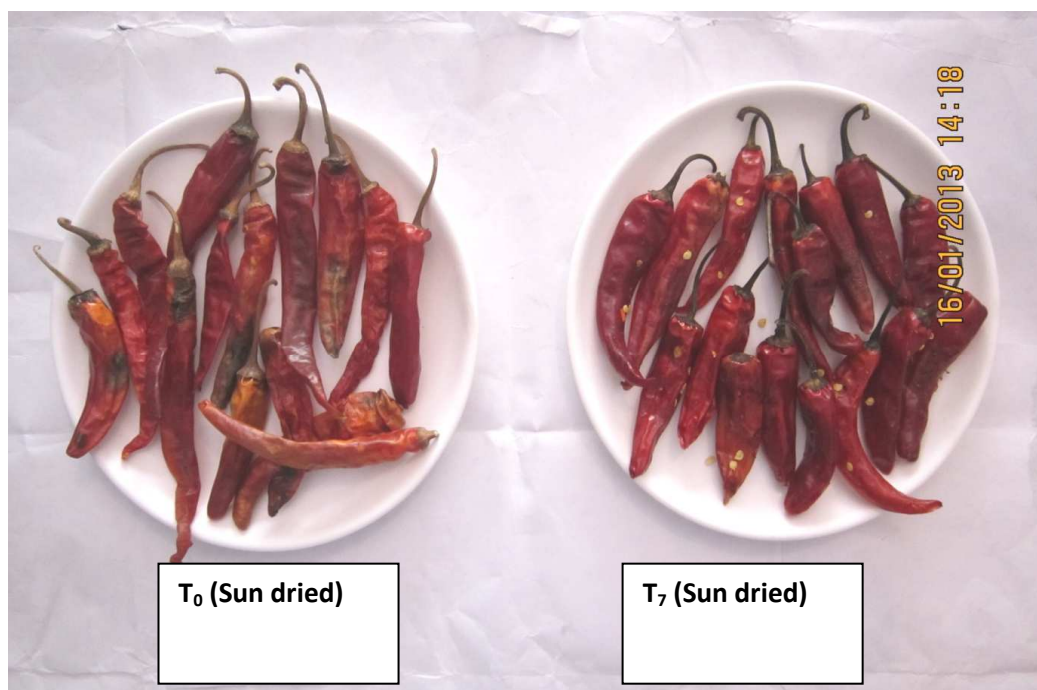
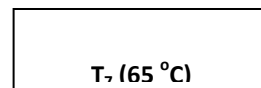
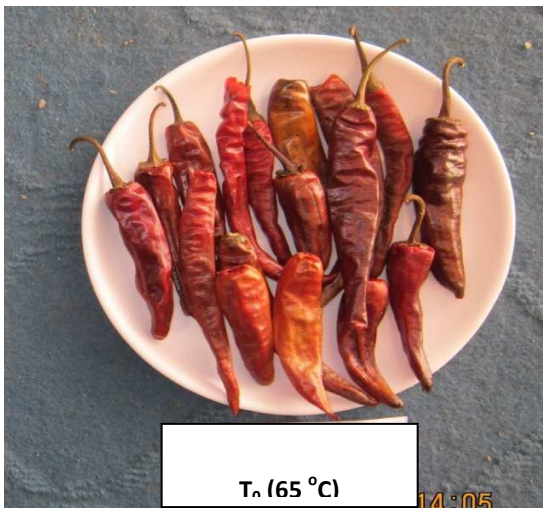
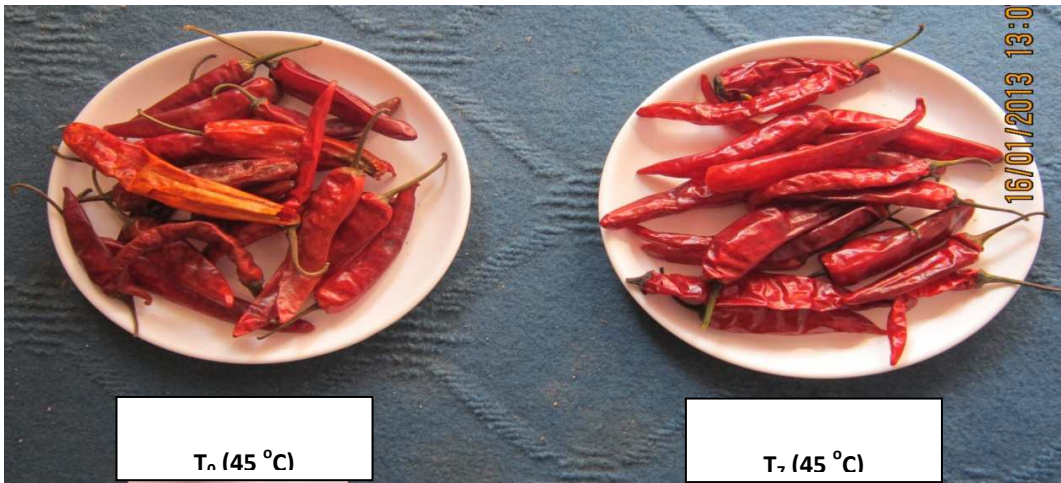


Plate-7 : Comparison of sun and solar pre-treated dried chillies (Kashmir Long-1)



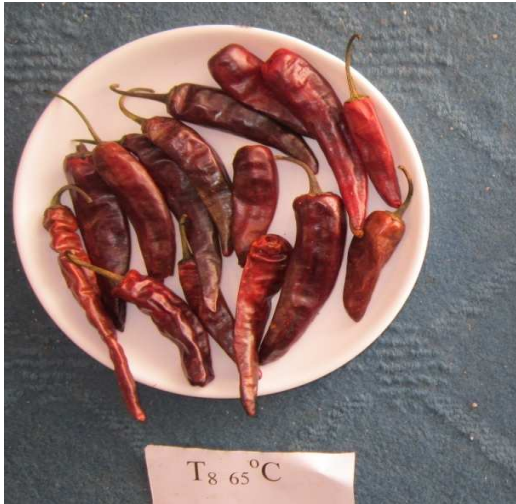


Plate-8 : Comparison of mechanical pre-treated dried chillies (Kashmir Long-1)

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

Ascorbic acid was estimated by taking 5g of sample, volume made upto 100 ml with (3%) metaphosphoric acid and filtered. Then aliquot of 10 ml was taken in a titration flask and titrated against 2,6-dichlorophenol indophenol till light pink colour appeared (which persisted for 15 seconds). Vitamin C was calculated using the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made up}}{\text{ml of filtrate taken for x weight of sample estimation}} \times 100$$

3.6.2.3 Capsaicin content (%)

The capsaicin content of red chillies was determined by Phosphomolybdenic acid method (Thimmiah, 2006). A standard curve of capsaicin was made by dissolving 50 mg of capsaicin in 50 ml acetone solution and volume was made upto 250 ml thereby taking 5 test tubes by pipetting out 5, 10, 15, 20, 25 ml of this solution in 100 ml flask and making volume to 100 ml by dry acetone and read the absorbance at 650 nm.

However after preparing standard curve 5 ml of 0.4 per cent NaOH and 3 ml of 3 per cent phospho molybdenic acid were added to the sample. Shaken for few minutes, the samples were filtered and allowed to stand for 1 hour and then centrifuged at 5000 rpm for 5-10 minutes and the absorbance was read at 650 nm using phospho molybdenic acid and dry acetone as blank.

$$\text{per cent Capsaicin} = \frac{\mu\text{g of capsaicin sample from standard curve} \times \text{dilution}}{\text{weight of sample estimation (g)} \times 1000} \times 100$$

3.6.2.4 Capsanthin ASTA (Extractable colour)

The capsanthin of red chilli samples was measured by the ASTA colour value using spectrophotometer. The ASTA colour value was measured using the ASTA analytical method 20.1 (1986). Ground chilli (70-100 mg) was added to 100 ml of acetone and then the mixture was stored at 0 °C for 4 hours with intermittent stirring. The absorbance of an aliquot of the transparent extract was

measured at 460 nm using spectrophotometer. ASTA colour value was calculated using following equation:

$$\text{ASTA colour value} = \frac{\text{Absorbance of acetone extracts} \times 16.4 \times I_f}{\text{Sample weight (g)}}$$

3.6.2.5 Reducing sugars (%)

Reducing sugars were estimated by phenol sulphuric acid method (Dubois *et al.*, 1956). Ground chilli seeds 100 mg were hydrolysed by keeping in boiling water bath for 3 hrs with 5 ml of 2.5N HCl and cooled to room temperature. The solution was neutralised with solid Na₂CO₃ until the effervescence ceases and the volume was made upto 100 ml with distilled water the contents were then centrifuged at 8000 rpm for 30 min at 27°C. 1 ml of supernatant was diluted to 100 ml with distilled water. About 1 ml diluted sample was transferred in test tube and 1ml of 5 percent phenol, 5 ml of concentrated sulphuric acid was added. The mixture was shaken well and kept in water bath maintained at 30 °C for 20 min. The absorbance of the solution was measured at 490 nm in spectrophotometer. Reducing sugar in test sample was calculated using standard graph prepared with standard solution of glucose.

3.6.2.6 Colour values (L*, a*, b*)

The L*, a*, b* colour values were observed by Hunter colourimeter (Model CR-2000, Minolta, Osaka, Japan), equipped with a 8-mm measuring head and a c illumination (6774 K). The meter was calibrated using the manufacturer's standard white plate. Colour changes were quantified in the L*, a*, b* colour space. L*, refers to lightness of the colour of the sample fruit and ranges from black = 0 to white = 100. A negative value of a* indicates a green colour where the positive value indicates red-purple colour. A positive value of b* indicates a yellow colour and the negative value a blue colour (McGuire, 1992).

3.6.2.7 Non-Enzymatic Browning (NEB)

Non-enzymatic browning (NEB) of red chillies was determined by method

given by Lee *et al.* (1991). Ground chillies 0.1 g were suspended in 50 ml of distilled water. The water soluble pigments were extracted for 2 hours by axially shaking at 25 °C and 140 rpm, and then the slurry was centrifuged at 8000 rpm for 8 min. The supernatant was filtered with the 0.45 µm pore size filter paper to remove suspended particles. The absorbance of the filtrate was recorded at 420 nm and 60 per cent alcohol as blank using a spectrophotometer.

3.6.2.8 Water activity

The moisture sorption isotherms describes relationship between water activity and the equilibrium moisture content for a food product to a constant pressure and temperature. Water activity was recorded by Aqualab water activity meter (Model series 3TE) and the readings were corrected at 20°C (AOAC, 1995). However, the moisture was recorded by the method described by AOAC (1995).

3.7 Statistical analysis

Experimental data was subjected to the statistical analysis following analytical procedures as described by Gomez and Gomez (1984). Level of significance used for F; and t; tests were $p \leq 0.05$ from the table given by Fisher (1970) and the data collected was subjected to statistical analysis using statistical software “STATISTICA-AG” from Stat Soft (USA) licensed to FOA, SKUAST-Kashmir, Wadura campus.

3.8 Mathematical modeling of drying curves and formulation (Drying kinetics)

Chillies were dried in conventional air dryer at 3 different temperatures viz. 45, 55 and 65 °C at ambient relative humidity and 1.2 m/s air velocity. The moisture ratio of chillies during drying experiment was calculated using the following equation:

$$MR = \frac{M - M_e}{M_0 - M_e} \text{ (Equation-I)}$$

Where, M is moisture content (%dry basis), M_e is equilibrium moisture content (%dry basis) and M_0 is initial moisture content (%dry basis)

The drying rate of chillies was calculated by Equation-II (Akpinar, 2002).

$$\text{Drying rate} = M_{t+dt} - M_t / dt$$

Where, M_{t+dt} is moisture content at $t+ dt$ (% dry basis)

For mathematical modeling, the drying equations were tested to select the best model for describing the drying curve of the chillies. The regression analysis was performed using the STATISTICA computer programme. The correlation coefficient (r) was the primary criterion for selecting the best equation to describe the drying curve (Guarte, 1996). In addition, the reduced chi-square (χ^2) and root mean square error analysis (RMSE) were used to determine the best fit. These parameters were calculated as follows:

$$\chi^2 = \frac{\sum_{i=1}^n (MR_{\text{exp}} - MR_{\text{pre}})^2}{N-n}$$

$$\text{RMSE} = [1/N \sum_{i=1}^N (MR_{\text{pre}} - MR_{\text{exp}})^2]^{1/2}$$

Where, MR_{exp} is the observed moisture ratio, MR_{pre} is the predicted moisture ratio, N the number of observations and n is the number constants (Sarsavadia *et al.*, 1999).

Three models viz. Newton model, Page model and Henderson-Pabis model were fitted on the data. The model equations given by these models are as:

The Page model:

$$MR = \exp(-kt^n)$$

The Newton model:

$$MR = \exp(-kt)$$

The Henderson-Pabis model:

$$MR = a \exp(-kt)$$

Where, MR represents the unaccomplished moisture content or moisture ratio, k is the drying rate constant, and n and a are constants.

The empirical constants for the thin-layer drying models were determined

experimentally from normalized drying curves at different temperatures, which were evaluated based on coefficient of determination (R^2).

The form of linearised Page equation is:

$$\ln [-\ln (\text{MR})] = \ln (k) + N \ln$$

Where, the drying constants, k and N , are determined from the intercept and slope of the $\ln(-\ln (\text{MR}))$ vs \ln curve, respectively.

The form of the linearised Newton equation is:

$$\ln (\text{MR}) = -kt + 1$$

and of the Henderson-Pabis equation is

$$\ln (\text{MR}) = -kt + a$$

Where, the drying constants k and a are determined from the slope and intercept, respectively, of the $\ln (\text{MR})$ vs. time curve. For the Newton equation, the intercept is set equal to 1.

The goodness of fit for each model was evaluated based on coefficient of determination R^2 , root mean square error (RMSE) and chi-square (χ^2). For quality fit of the model R^2 (coefficient of determination) should be close to one. As root mean square error (RMSE) and chi-square (χ^2) approach zero, the closer the prediction is to experimental data. The predicted moisture ratio was compared to the experimental moisture ratio using (RMSE) and (χ^2) as shown in equation above (Akpınar *et al.*, 2003).

Chapter – 4

EXPERIMENTAL FINDINGS

The present investigation “Effect of drying methods and packaging materials on storage stability and quality of chillies” was carried under three experiments:

- Experiment No.1: Effect of pre-treatments, drying methods and storage period on quality of whole chillies (Kashmir Long-1).
- Experiment No.2: Effect of pre-treatments, mechanical drying temperatures and storage period on quality of chillies (Kashmir Long-1).
- Experiment No.3: Effect of packaging materials and storage period on quality attributes of chilli powder.

In the above experiments the physico-chemical properties were assessed at different storage intervals. The salient findings of the experiments are mentioned as under:

4.1 Physico-chemical characteristics of fresh chilli (Kashmir Long 1)

Table 1 reveals the physico-chemical characteristics of fresh chilli (*Capsicum annum*) var. Kashmir Long-1. Physical parameters recorded revealed that freshly harvested red chilli had an average length 11.21 cm, breadth 1.57 cm, average fruit weight 9.060 g and seed content 34 per cent. Chemical composition of chilli revealed that it contained 80.686 per cent moisture (wb) and 417.75% (db) and 0.648 per cent db reducing sugar. It had an ascorbic acid of 49.4 mg/100g (db), 0.38 per cent capsaicin (db) and 98.378 ASTA units capsanthin. The colour values revealed that it had L*, a*, b* values of 32.666, 20.913 and 35.805 respectively.

Table-1 : Physico-chemical characteristics of fresh chilli (Kashmir Long-1)

S. No.	Parameter	Mean±SEM
1.	Length (cm)	11.21±0.23
2.	Breadth (cm)	1.57±0.04
3.	Weight (g)	9.060±0.19
4.	Seed (%)	34±0.70
5.	Moisture	417.75 (db),80.68 (wb)±1.67
6.	Ascorbic acid (mg/100g db)	49.4±1.03
7.	Capsaicin content (%db)	0.38±0.007
8.	Reducing sugar (%db)	0.648±0.01
9.	Capsanthin (ASTA value)	98.378±2.04
10.	Colour values:	
	L*	32.666±0.43
	a*	20.913±0.27
	b*	35.805±0.47

4.2 Experiment No. 1: Effect of pre-treatments, drying methods and storage period on quality of whole chillies (Kashmir Long-1)

4.2.1 Physico-chemical characteristics of dried chilli

4.2.1.1 Moisture content (db%)

Effect of pre-treatments, drying methods and storage period on moisture (% db) of chilli samples is depicted in Table 2.

The initial moisture content of fresh chillies was 80.68% wb and 418.53% db. During drying operation there was reduction in moisture content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments and methods of drying. At the completion of drying process, the moisture content of open sun dried samples at (0) days of storage was significantly higher than solar tunnel dried samples in all treatments. The moisture content recorded in open sun dried samples without any pre-treatment was maximum 14.45% db whereas, the moisture content of pre-treated samples varied from 10.43 to 13.65% db. Minimum moisture content (10.43% db) was recorded in samples dried by using T_7 as pre-treatment solution followed by 10.94%db in samples pretreated with T_6 solution. The moisture content of chilli samples at the completion of solar tunnel drying was maximum (13.43% db) in control samples and a lower value of 9.85 to 12.75%db was recorded in pre-treated samples. Minimum moisture (9.85%db) was recorded in samples which were dried after using T_7 as pre-treatment followed by 10.19%db in samples pretreated with T_6 solution.

The moisture content of chilli samples increased during storage non-significantly in all samples. Higher mean moisture content during 120 days of storage were observed in open sun dried samples (13.02% db) compared to (12.40%db) in solar tunnel dried samples.

The mean moisture content of sun dried samples at 30, 60, 90 and 120 days of storage was 12.83, 13.19, 13.32, 13.45 compared to the lower values of 12.18, 12.61, 12.79, 12.96%db respectively in solar tunnel dried samples, irrespective of treatments.

Table-2 :Effect of pretreatments, drying methods and storage period on moisture (%db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]											Overall mean	
	Sun drying					Mean	Solar tunnel drying						Mean
	0	30	60	90	120		0	30	60	90	120		
T ₀	14.45	15.05	15.36	15.51	15.63	15.20	13.43	14.17	14.53	14.70	14.85	14.33	14.77
T ₁	13.65	13.94	14.27	14.33	14.53	14.14	12.75	13.47	13.85	14.00	14.13	13.64	13.89
T ₂	13.05	13.75	14.09	14.22	14.35	13.89	12.02	12.75	13.15	13.31	13.45	12.93	13.41
T ₃	12.52	13.16	13.52	13.68	13.81	13.33	11.64	12.38	12.77	12.95	13.11	12.57	12.95
T ₄	12.04	12.69	13.03	13.17	13.28	12.84	11.43	12.17	12.61	12.75	12.88	12.37	12.60
T ₅	11.43	12.07	12.39	12.52	12.64	12.21	10.59	11.17	11.36	11.62	11.85	11.32	11.76
T ₆	10.94	11.64	11.93	12.01	12.17	11.73	10.19	11.28	11.65	11.87	12.10	11.41	11.57
T ₇	10.43	10.48	11.09	11.20	11.34	10.91	9.85	10.16	11.05	11.23	11.42	10.74	10.82
Mean	12.30	12.83	13.19	13.32	13.45	13.02	11.47	12.185	12.61	12.79	12.96	12.40	
Storage mean	11.89	12.50	12.90	13.05	13.21								

C.D(p≤0.05)

Treatment (T)	=	0.623
Storage (S)	=	N.S
Drying methods (DM)	=	0.312
T x S	=	1.394
T x DM	=	N.S
S x DM	=	N.S
T x S x DM	=	N.S

Irrespective of drying methods and storage periods the untreated samples possessed over all mean moisture content (14.77% db) compared to lower values (10.82 to 13.89% db) in treated samples. Minimum moisture content 10.82 and 11.57% db was recorded in samples pre-treated with T₇ and T₆ solution respectively.

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant increase in moisture content during 120 days of storage. The overall moisture content recorded increased from 11.89% db at 0 days of storage to a maximum value of 13.21% db at end of 120 days of storage.

4.2.1.2 Ascorbic acid (mg/100g db)

Effect of pre-treatments, drying methods and storage periods on ascorbic acid (mg/ 100 g db) of chilli samples is depicted in Table 3.

The initial ascorbic acid content of fresh chillies was 49.4 mg/100g (db). Pre-treatments, methods of drying and storage periods influenced significantly ($p \leq 0.05$) the ascorbic acid content in chilli samples. At the completion of drying process, the ascorbic acid of solar tunnel dried samples at 0 days of storage was significantly ($p \leq 0.05$) higher than sun dried samples in all treatments. The ascorbic acid content of pre treated sundried samples varied from 38.70 to 39.98 mg/100g db at (0) days of storage and control samples recorded the ascorbic acid content of 38.52 mg/100 g db. Maximum ascorbic acid content of 39.98 mg/100g was recorded in sun dried samples pretreated with T₇ solution.

The ascorbic acid content of pre-treated solar tunnel dried samples at (0) days of storage ranged from 39.47 to 41.08 mg/100g db and control samples recorded 39.47 mg/100g db ascorbic acid. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum ascorbic acid of 41.08 mg/100g db followed by T₆ pre-treated samples (40.93 mg/100g db).

Table-3 : Effect of pretreatments, drying methods and storage period on ascorbic acid (mg/100g db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]											Overall mean	
	Sun drying					Mean	Solar tunnel drying						Mean
	0	30	60	90	120		0	30	60	90	120		
T ₀	38.52	38.20	37.93	37.25	36.98	37.78	39.47	39.29	39.03	38.36	38.07	38.85	38.31
T ₁	38.70	38.49	38.21	37.58	37.29	38.06	39.62	39.46	39.18	38.55	38.26	39.02	38.54
T ₂	39.00	38.81	38.54	37.86	37.55	38.35	39.92	39.74	39.48	38.79	38.49	39.28	38.82
T ₃	39.13	38.92	38.65	38.00	37.73	38.49	40.11	39.93	39.66	39.00	38.73	39.49	38.99
T ₄	39.30	39.01	38.73	38.00	37.81	38.57	40.38	40.11	39.86	39.11	38.92	39.68	39.13
T ₅	39.26	39.05	38.77	38.18	37.81	38.62	40.25	40.02	39.68	39.12	38.79	39.57	39.10
T ₆	39.90	39.69	39.39	38.62	38.38	39.20	40.93	40.86	40.59	39.84	39.68	40.38	39.79
T ₇	39.98	39.56	39.38	38.72	38.48	39.22	41.08	40.75	40.67	40.01	39.72	40.44	39.83
Mean	39.23	38.97	38.70	38.03	37.76	38.53	40.22	40.02	39.77	39.10	38.84	39.59	
Storage mean	39.72	39.49	39.23	38.56	38.30								

C.D(p≤0.05)

Treatment (T)	=	0.795
Storage (S)	=	0.722
Drying methods (DM)	=	0.571
T x S	=	1.778
T x DM	=	N.S
S x DM	=	N.S
T x S x DM	=	N.S

Irrespective of pretreatments and storage days higher mean ascorbic acid values at all sampling dates were observed in solar tunnel dried samples (39.59 mg/100g db) compared to (38.53 mg/100g db) in open sun dried samples.

The mean ascorbic acid content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 38.97, 38.70, 38.03, 37.76 mg/100g db compared to the lower values of 40.02, 39.77, 39.10, 38.84mg/100g db respectively in open sun dried samples, irrespective of treatments.

Irrespective of drying methods and storage period the samples pre-treated with T₇solution possessed maximum overall mean ascorbic acid content (39.83 mg/100g db) compared to minimum ascorbic acid content of 38.31 mg/100g db recorded in control samples.

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant decrease in ascorbic acid content during 120 days of storage. The ascorbic acid content decreased from 39.72 mg/100g db at 0 days of storage to a minimum value of 38.30 mg/100g db at end of 120 days of storage.

4.2.1.3 Capsaicin content (%db)

Effect of pre-treatments, drying methods and storage period on capsaicin (%db) of whole chilli samples is depicted in Table 4.

The initial capsiacin content of fresh chillies was 0.38% (db). Pre-treatments and methods of drying influenced significantly ($p \leq 0.05$) the capsiacin content in chilli samples. At the completion of drying process, the capsiacin content of solar tunnel dried samples at (0) days of storage was significantly higher than sun dried samples in all treatments. The capsiacin content of pre-treated samples varied from 0.893 to 0.939% db in sun dried samples at (0) days of storage. However control samples recorded the capsaicin content of 0.893% db. The capsiacin content recorded in open sun dried samples using pre-treatment

Table-4 :Effect of pretreatments, drying methods and storage period on capsaicin (%db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]											Overall mean	
	Sun drying					Mean	Solar tunnel drying						Mean
	0	30	60	90	120		0	30	60	90	120		
T ₀	0.893	0.844	0.800	0.774	0.727	0.808	0.975	0.918	0.852	0.846	0.841	0.887	0.847
T ₁	0.893	0.839	0.806	0.779	0.725	0.809	0.993	0.937	0.872	0.862	0.851	0.903	0.856
T ₂	0.897	0.850	0.823	0.790	0.729	0.818	0.999	0.932	0.880	0.870	0.858	0.908	0.863
T ₃	0.901	0.859	0.831	0.806	0.753	0.830	1.010	0.970	0.921	0.890	0.861	0.931	0.908
T ₄	0.910	0.871	0.851	0.825	0.774	0.846	1.016	0.974	0.924	0.897	0.871	0.937	0.892
T ₅	0.918	0.879	0.859	0.836	0.793	0.857	1.033	0.998	0.944	0.909	0.876	0.952	0.905
T ₆	0.925	0.896	0.882	0.852	0.796	0.870	1.053	1.019	0.978	0.945	0.911	0.982	0.926
T ₇	0.939	0.902	0.908	0.867	0.792	0.882	1.077	1.036	1.000	0.958	0.919	0.998	0.940
Mean	0.910	0.868	0.845	0.816	0.761	0.840	1.020	0.973	0.922	0.897	0.874	0.938	
Storage mean	0.96	0.92	0.90	0.85	0.81								

C.D(p≤0.05)

Treatment (T)	=	0.039
Storage (S)	=	NS
Drying methods (DM)	=	0.020
T x S	=	0.088
T x DM	=	N.S
S x DM	=	N.S
T x S x DM	=	N.S

T₇ was maximum 0.939% db followed by (0.925% db) in samples pretreated with T₆solution.

The capsaicin content of pretreated samples dried under solar tunnel drier ranged from 0.993 to 1.077% db and control samples recorded 0.975% db capsaicin. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum capsaicin content of 1.077% followed by T₆(1.053% db).

Higher mean capsaicin content values at all sampling dates were observed in solar tunnel dried samples (0.938%db) compared to (0.840%db) in open sun dried samples irrespective of pretreatments and storage days.

The mean capsaicin content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 0.973, 0.922, 0.897, 0.874 compared to the lower values of 0.868, 0.845, 0.816, 0.761% in open sun dried samples, irrespective of treatments.

Irrespective of drying methods and storage period the samples pre-treated with T₇possessed maximum overall mean capsaicin content (0.940% db) compared to minimum capsaicin content of 0.847% db recorded in control samples.

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant decrease in capsaicin content during 120 days of storage. The capsaicin content recorded decreased from 0.965% db at (0) days of storage to a minimum value of 0.817% db at end of 120 days of storage.

4.2.1.4 Capsanthin content (ASTA units)

Effect of pre-treatments, drying methods and storage period on capsanthin (ASTA units) of chilli samples is depicted in Table 5.

The initial capsanthin content of fresh chillies was 98.378 ASTA units fresh weight basis. Pre-treatments, drying methods and storage period influenced

significantly ($p \leq 0.05$) the capsanthin content in chilli samples. At the completion of drying process, the capsanthin content of solar tunnel dried samples at 0 days of storage was significantly higher than open sun dried samples in all treatments. The capsanthin content of pre treated sun dried samples varied from 114.06 to 119.45 ASTA Units at (0) day of storage, however control samples recorded the capsanthin content of 113.64 ASTA Units. The capsanthin content recorded in open sun dried samples using pretreatment T₇ was maximum 119.45 ASTA units.

The capsanthin content of pretreated samples dried under solar tunnel drier ranged from 115.74 to 121.51 ASTA Units and control samples recorded 115.19 ASTA Units at (0) day of storage. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum capsanthin content of 121.51 ASTA Units followed by T₆ (121.30 ASTA Units).

Higher mean capsanthin content values during 120 days of storage were observed in solar tunnel dried samples (117.38 ASTA units) compared to (115.75 ASTA units) in open sun dried samples.

The mean capsanthin content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 118.11, 117.61, 116.74, 116.05 ASTA units compared to the lower values of 116.32, 116.22, 115.27, 114.45 ASTA units respectively in open sun dried samples, irrespective of treatments.

Irrespective of drying methods and storage period the samples pre-treated with T₇ solution possessed over all mean capsanthin content (119.62 ASTA units) whereas, minimum capsanthin content of 113.61 ASTA units was recorded in control samples.

Irrespective of pre-treatments and drying methods the chilli samples exhibited significant decrease in capsanthin content during 120 days of storage. The capsanthin content decreased from 117.42 ASTA units at 0 days of storage to a minimum value of 115.25 ASTA units at end of 120 days of storage.

Table-5 : Effect of pretreatments, drying methods and storage period on capsanthin (ASTA units) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]											Overall mean	
	Sun drying					Mean	Solar tunnel drying						Mean
	0	30	60	90	120		0	30	60	90	120		
T ₀	113.64	113.58	113.48	112.68	111.77	113.03	115.19	114.93	114.47	113.50	112.88	114.19	113.61
T ₁	114.06	113.79	113.66	112.64	111.85	113.20	115.74	115.54	114.96	114.02	113.05	114.66	113.93
T ₂	115.62	115.49	115.48	114.48	113.57	114.93	116.34	116.12	115.56	114.55	114.04	115.32	115.12
T ₃	115.95	115.88	115.83	114.92	114.09	115.33	117.71	117.47	117.01	116.13	115.23	116.71	116.02
T ₄	116.38	116.21	116.08	114.91	114.36	115.59	118.82	118.55	117.85	117.24	116.73	117.84	116.71
T ₅	117.39	117.31	117.25	116.51	115.40	116.77	120.33	120.28	119.57	118.65	117.96	119.36	118.06
T ₆	119.31	119.21	119.12	117.86	117.41	118.58	121.30	120.68	120.31	119.83	119.00	120.22	119.40
T ₇	119.45	119.10	118.92	118.16	117.14	118.55	121.51	121.32	121.13	120.04	119.47	120.69	119.62
Mean	116.47	116.32	116.22	115.27	114.45	115.75	118.37	118.11	117.61	116.74	116.05	117.38	
Storage mean	117.42	117.21	116.91	116.00	115.25								

C.D(p≤0.05)

Treatment (T)	=	0.032
Storage (S)	=	0.044
Drying methods (DM)	=	0.071
T x S	=	4.665
T x DM	=	N.S
S x DM	=	N.S
T x S x DM	=	N.S

4.2.1.5 Reducing sugar (% db)

Effect of pre-treatments, drying methods and storage period on reducing sugar (% db) of chilli samples is depicted in Table 6.

The initial reducing sugar content of fresh chillies was 0.648% db. Pre-treatments, methods of drying and storage influenced significantly ($p \leq 0.05$) the reducing sugar content in chilli samples. At the completion of drying process, the reducing sugar content of solar tunnel dried samples at 0 days of storage was significantly higher than open sun dried samples in all treatments. The reducing sugar content of pre-treated sun dried samples varied from 0.583 to 0.591% db. However control samples recorded the reducing sugar content of 0.582% db. The reducing sugar content recorded in open sun dried samples using pre-treatment T₇ was maximum 0.591% db followed by (0.590% db) in samples pretreated with T₆ solution.

The reducing sugar content of pretreated samples dried under solar tunnel drier ranged from 0.613 to 0.617% db and control samples recorded reducing sugar content of 0.611% db. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum reducing sugar content of 0.617% db which was found at par with samples pretreated with T₆ solution.

Higher mean reducing sugar content values at all sampling dates were observed in solar tunnel dried samples (0.533% db) compared to (0.511% db) in open sun dried samples irrespective of pretreatments and storage period.

The reducing sugar content of chilli samples decreased during storage significantly in all samples. The mean reducing sugar content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 0.574, 0.546, 0.487, 0.441% db compared to the lower values of 0.563, 0.514, 0.464, 0.425% db respectively in open sun dried samples, irrespective of treatments.

Irrespective of drying methods and storage period the T₇ sample treated with T₇ solution possessed maximum mean reducing sugar content (0.526% db) and minimum reducing sugar content of 0.516% db was recorded in control samples.

Table-6 : Effect of pretreatments, drying methods and storage period on reducing sugar (% db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]											Overall mean	
	Sun drying					Mean	Solar tunnel drying						Mean
	0	30	60	90	120		0	30	60	90	120		
T ₀	0.582	0.558	0.511	0.461	0.415	0.505	0.611	0.570	0.542	0.475	0.438	0.528	0.516
T ₁	0.583	0.561	0.512	0.461	0.418	0.507	0.613	0.570	0.541	0.483	0.440	0.529	0.518
T ₂	0.584	0.562	0.513	0.464	0.421	0.509	0.614	0.573	0.544	0.487	0.440	0.532	0.520
T ₃	0.587	0.564	0.514	0.464	0.422	0.510	0.614	0.573	0.545	0.488	0.440	0.532	0.521
T ₄	0.587	0.564	0.514	0.465	0.425	0.511	0.615	0.574	0.547	0.491	0.441	0.534	0.522
T ₅	0.587	0.564	0.515	0.466	0.426	0.512	0.616	0.576	0.549	0.491	0.441	0.535	0.523
T ₆	0.590	0.566	0.516	0.467	0.431	0.514	0.617	0.577	0.549	0.491	0.443	0.536	0.525
T ₇	0.591	0.567	0.516	0.468	0.439	0.516	0.617	0.577	0.550	0.492	0.444	0.536	0.526
Mean	0.586	0.563	0.514	0.464	0.425	0.511	0.615	0.574	0.546	0.487	0.441	0.533	
Storage mean	0.600	0.568	0.530	0.475	0.433								

C.D (p≤0.05)

Treatment (T)	=	0.022
Storage (S)	=	0.017
Drying methods (DM)	=	0.031
T x S	=	N.S
T x DM	=	N.S
S x DM	=	N.S
T x S x DM	=	N.S

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant decrease in reducing sugar content during 120 days of storage. The reducing sugar content recorded decreased from 0.600% db at 0 days of storage to a minimum value of 0.433% db at end of 120 days of storage.

4.2.1.6 Non enzymatic browning

Effect of pre-treatments, drying methods and storage period on non-enzymatic browning values of chilli samples has been depicted in Table 7.

During drying operation there was increase in non enzymatic browning values of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments and storage. At the completion of drying process, the non enzymatic browning values of open sun dried samples at (0) days of storage was significantly higher than solar tunnel dried samples in all treatments. The non-enzymatic browning values recorded in open sun dried samples without any pre-treatment was maximum 0.150 at 0 days of storage where as the non-enzymatic browning values of pre-treated samples varied from 0.146 to 0.149. Minimum non-enzymatic browning value of (0.146) was recorded in samples dried by using T₇ as pre-treatment solution followed by 0.146 in T₆ pretreated samples. The non-enzymatic browning value of chilli samples at the completion of solar tunnel drying at (0) days of storage was maximum (0.125) in control samples and a lower value of 0.123 to 0.125 was recorded in pre-treated samples. Minimum non-enzymatic browning values of (0.123) was recorded in samples which were dried after using T₇ as pre-treatment followed by 0.124 in T₆ pretreated samples.

The non enzymatic browning values of chilli samples increased significantly during storage in all treatments. Higher mean non enzymatic browning values were observed in open sun dried samples (0.167) compared to (0.135) in solar tunnel dried samples irrespective of pretreatment and storage.

Table-7 : Effect of pretreatments, drying methods and storage period on non-enzymatic browning values(OD at 420nm) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]											Overall mean	
	Sun drying					Mean	Solar tunnel drying						Mean
	0	30	60	90	120		0	30	60	90	120		
T ₀	0.150	0.164	0.171	0.180	0.185	0.170	0.125	0.131	0.137	0.142	0.148	0.137	0.153
T ₁	0.149	0.162	0.169	0.176	0.183	0.168	0.125	0.131	0.136	0.142	0.147	0.136	0.152
T ₂	0.148	0.163	0.169	0.179	0.183	0.168	0.124	0.130	0.136	0.141	0.146	0.135	0.152
T ₃	0.148	0.162	0.168	0.178	0.182	0.168	0.124	0.130	0.136	0.141	0.146	0.135	0.151
T ₄	0.147	0.162	0.168	0.177	0.181	0.167	0.124	0.130	0.136	0.141	0.146	0.135	0.151
T ₅	0.147	0.161	0.167	0.177	0.180	0.166	0.124	0.130	0.135	0.141	0.146	0.135	0.150
T ₆	0.147	0.161	0.167	0.176	0.180	0.166	0.124	0.129	0.135	0.140	0.145	0.135	0.150
T ₇	0.146	0.160	0.166	0.175	0.178	0.165	0.123	0.129	0.134	0.140	0.145	0.134	0.149
Mean	0.148	0.162	0.168	0.177	0.181	0.167	0.124	0.130	0.136	0.141	0.146	0.135	
Storage mean	0.136	0.146	0.152	0.159	0.164								

C.D (p≤0.05)

Treatment (T)	=	0.006
Storage (S)	=	0.005
Drying methods (DM)=	NS	
T x S	=	N.S
T x DM	=	N.S
S x DM	=	N.S
T x S x DM	=	N.S

The mean non enzymatic browning values of sun dried samples at 30, 60, 90 and 120 days of storage were 0.162, 0.168, 0.177, 0.181 compared to the lower values of 0.130, 0.136, 0.141, 0.146 respectively in solar tunnel dried samples, irrespective of treatments.

Irrespective of drying methods and storage period the untreated samples possessed maximum over all mean non enzymatic browning value of (0.153) compared to lower values (0.149 to 0.152) in treated samples.

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant increase in non enzymatic browning values during 120 days of storage. The non enzymatic browning values increased from 0.136 at 0 days of storage to a maximum value of 0.164 at end of 120 days of storage.

4.2.1.7 Colour values (L, a*, b*, c, h (ΔE)) in sun dried chilli.

The colour parameters of chilli samples after sun drying and during storage as influenced by pretreatment applications are presented in Table 8. On day (0) all the treated samples had highest L*, a*, b*, c values which significantly ($p \leq 0.05$) decreased with storage period, while as, h and (ΔE) value had significantly increased. The untreated samples had L* value of 27.65, whereas treated samples have L* values of 28.07 to 30.52 at (0) days of storage.

Maximum L* value of 30.52 was recorded in samples pretreated with T₇ solution at (0) days of storage. The L* values recorded after 120 days of storage varied from 26.46 to 29.15 in treated samples compared to L* value of 26.00 in control samples. Maximum L* value was observed in samples pretreated with T₇ solution. The untreated samples had a* value of 21.76, whereas treated samples have a* values of 21.96 to 24.23. Maximum a* value of 24.23 was recorded in samples pretreated with T₇ solution at (0) days of storage. The a* values recorded after 120 days of storage varied from 19.50 to 22.59 in treated samples compared to a* value of 19.13 in control samples. Maximum a* value was observed in samples pretreated with T₇ solution. The untreated samples had b* value of 11.78,

Table-8 : Effect of pretreatments, sun drying method and storage period on L*,a*,b* in of chillies (Kashmir Long-1)

Colour Value	Storage days	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
L	0	27.65	28.07	28.37	28.76	29.15	29.46	29.84	30.52	28.98
	30	27.27	27.63	27.98	28.4	28.76	29.15	29.54	30.18	28.61
	60	26.86	27.26	27.59	28.06	28.43	28.86	29.23	29.84	28.27
	90	26.4	26.89	27.23	27.69	28.07	28.48	28.94	29.52	27.90
	120	26	26.46	26.88	27.28	27.72	28.21	28.61	29.15	27.54
	Mean	26.84	27.26	27.61	28.04	28.42	28.83	29.23	29.84	
a	0	21.76	21.96	22.36	22.75	23.13	23.47	23.88	24.23	22.94
	30	21.15	21.36	21.74	22.19	22.53	22.96	23.35	23.79	22.38
	60	20.46	20.74	21.15	21.58	21.98	22.32	22.88	23.33	21.81
	90	19.77	20.12	20.44	21.05	21.42	21.79	22.3	23	21.24
	120	19.13	19.5	19.88	20.36	20.85	21.24	21.82	22.59	20.67
	Mean	20.45	20.74	21.11	21.59	21.98	22.36	22.85	23.39	
b	0	11.78	11.87	12	12.12	12.22	12.35	12.56	12.68	12.20
	30	11.52	11.63	11.77	11.85	11.97	12.14	12.3	12.41	11.95
	60	11.35	11.4	11.51	11.6	11.77	11.84	12.04	12.12	11.70
	90	11.15	11.15	11.24	11.46	11.48	11.66	11.78	11.92	11.48
	120	10.98	10.96	11.01	11.2	11.24	11.36	11.49	11.69	11.24
	Mean	11.36	11.4	11.51	11.65	11.74	11.87	12.04	12.16	

Contd...

Table-8 contd...

Colour Value	Storage days	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
c	0	24.74	24.96	25.38	25.78	26.16	26.52	26.98	27.35	25.98
	30	24.08	24.32	24.72	25.16	25.51	25.97	26.39	26.83	25.37
	60	23.4	23.67	24.08	24.5	24.93	25.27	25.85	26.29	24.75
	90	22.7	23	23.33	23.97	24.3	24.71	25.22	25.91	24.14
	120	22.6	21.98	22.73	23.24	23.69	24.09	24.66	25.44	23.55
	Mean	23.50	23.59	24.05	24.53	24.92	25.31	25.82	26.36	
h	0	28.4	28.4	28.2	28	27.8	27.8	27.7	27.6	27.99
	30	28.6	28.6	28.4	28.1	28	27.9	27.8	27.5	28.11
	60	29	28.8	28.6	28.3	28.2	27.9	27.8	27.5	28.26
	90	29.4	29	28.8	28.6	28.2	28.2	27.8	27.4	28.43
	120	29.9	29.9	29	28.8	28.3	28.1	27.8	27.4	28.65
	Mean	29.06	28.94	28.60	28.36	28.10	27.98	27.78	27.48	
ΔE	0	0	0.47	0.96	1.52	2.08	2.56	3.14	3.89	1.83
	30	0	0.43	0.96	1.57	2.08	2.68	3.26	4.03	1.87
	60	0	0.49	1.01	1.66	2.23	2.78	3.46	4.21	1.98
	90	0	0.60	1.07	1.85	2.37	2.95	3.64	4.56	2.13
	120	0	0.59	1.16	1.79	2.45	3.08	3.78	4.73	2.20
	Mean	0	0.52	1.03	1.68	2.24	2.81	3.46	4.28	

CD (p≤0.05)

Treatment (T) = 0.072
Storage (S) = 0.101
TxS = 0.291

whereas treated samples have b^* values of 11.87 to 12.68. Maximum b^* value of 12.68 was recorded in samples pretreated with T_7 solution at (0) days of storage. The b^* values recorded after 120 days of storage varied from 10.96 to 11.69 in treated samples compared to b^* value of 10.98 in control samples. Maximum b^* value was observed in samples pretreated with T_7 solution.

The untreated samples had c value of 24.74, whereas treated samples have c values of 24.96 to 27.35. The c values recorded after 120 days of storage varied from 21.98 to 25.44 in treated samples compared to c value of 22.60 in control samples. Maximum c value was observed in samples pretreated with T_7 solution. Maximum c value of 27.35 was recorded in samples pretreated with T_7 solution at (0) days of storage.

The untreated samples had h value of 28.40 which is found at par with samples pretreated with T_1 solution, whereas treated samples have h values of 27.60 to 28.40. The h values recorded after 120 days of storage varied from 27.4 to 29.90 in treated samples compared to h value of 29.90 in control samples. Maximum h value was observed in control samples at (0) days of storage. Maximum h value of 29.90 was recorded in control and samples pretreated with T_1 solution at 120 days of storage.

The untreated samples had (ΔE) value of 0.000, whereas treated samples have (ΔE) values of 0.474 to 3.892. The (ΔE) values recorded after 120 days of storage varied from 0.591 to 4.733 in treated samples compared to L^* value of 0.000 in control samples. Maximum (ΔE) value was observed in samples pretreated with T_7 solution. Maximum (ΔE) value of 4.733 was recorded in samples pretreated with T_7 solution at 120 days of storage.

4.2.1.8 Colour values (L^* , a^* , b^* , c , h (ΔE)) in solar tunnel dried chilli.

The colour parameters of chilli samples after solar tunnel drying and during storage as influenced by pretreatment applications are presented in Table 9. On day (0) all the treated samples had highest L , a^* , b^* , c values which

Table-9 : Effect of pretreatments, tunnel drying method and storage period on L*,a*,b* in of chillies (Kashmir Long-1)

Colour Value	Storage days	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
L	0	28.7	29.05	29.42	29.82	30.17	30.51	30.88	31.56	30.01
	30	28.28	28.66	29.05	29.44	29.82	30.2	30.57	31.22	29.65
	60	27.86	28.26	28.66	29.07	29.45	29.86	30.25	30.86	29.28
	90	27.43	27.9	28.28	28.73	29.11	29.55	29.94	30.53	28.93
	120	27.03	27.51	27.92	28.31	28.76	29.24	29.64	30.2	28.58
	Mean	27.86	28.28	28.67	29.07	29.46	29.87	30.26	30.87	
a	0	22.81	23.01	23.42	23.78	24.15	24.54	24.93	25.23	23.98
	30	22.15	22.39	22.79	23.19	23.58	23.97	24.41	24.83	23.41
	60	21.47	21.74	22.15	22.62	22.98	23.36	23.88	24.39	22.82
	90	20.78	21.15	21.51	22.09	22.43	22.8	23.37	24.01	22.27
	120	20.15	20.52	20.91	21.43	21.87	22.24	22.86	23.61	21.70
	Mean	21.47	21.76	22.16	22.62	23	23.38	23.89	24.41	
b	0	12.5	12.62	12.76	12.84	12.97	13.14	13.28	13.44	12.94
	30	12.3	12.39	12.52	12.61	12.73	12.89	13.02	13.18	12.71
	60	12.09	12.16	12.27	12.38	12.48	12.63	12.75	12.91	12.46
	90	11.88	11.94	12.03	12.18	12.25	12.38	12.49	12.66	12.23
	120	11.69	11.71	11.8	11.92	12.02	12.14	12.24	12.41	11.99
	Mean	12.09	12.16	12.28	12.39	12.49	12.64	12.76	12.92	

Contd...

Table-9 contd...

Colour Value	Storage days	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
c	0	26.1	26.24	26.67	27.3	27.41	27.84	28.25	28.59	27.30
	30	25.34	25.51	26	26.4	26.8	27.17	27.67	28.11	26.63
	60	24.64	24.91	25.32	25.79	25.99	26.56	27.5	27.6	26.04
	90	23.94	24.29	24.65	25.15	25.56	25.94	26.5	27.14	25.40
	120	23.3	23.63	24.1	24.52	24.96	25.34	25.93	23.67	24.43
	Mean	24.66	24.92	25.35	25.83	26.14	26.57	27.17	27.02	
h	0	28.7	28.7	28.6	28.4	28.2	28.2	28	28	28.35
	30	29	29.1	28.8	28.5	28.4	28.1	28.1	28	28.50
	60	29.4	29.2	29	28.7	28.7	28.4	28.1	27.9	28.68
	90	29.8	29.4	29.2	29	28.6	28.5	28.1	27.8	28.80
	120	30.1	29.7	29.4	29.1	28.8	28.6	28.2	27.7	28.95
	Mean	29.4	29.22	29	28.74	28.54	28.36	28.1	27.88	
ΔE	0	0	0.41	0.98	1.518	2.043	2.587	3.137	3.863	1.82
	30	0	0.46	1.024	1.59	2.143	2.704	3.297	4.072	1.91
	60	0	0.49	1.063	1.694	2.227	2.805	3.463	4.264	2.00
	90	0	0.6	1.131	1.874	2.384	2.975	3.659	4.545	2.15
	120	0	0.606	1.176	1.825	2.462	3.075	3.802	4.748	2.21
	Mean	0	0.52	1.07	1.7	2.25	2.83	3.47	4.3	

CD (p≤0.05)

Treatment (T) = 0.063
Storage (S) = 0.027
TxS = 0.190

significantly ($p \leq 0.05$) decreased with storage period, while as, h and (ΔE) value had significantly increased. The untreated samples had L value of 28.70, whereas treated samples have L values of 29.05 to 31.56. Maximum L value of 31.56 was recorded in samples pretreated with T₇ solution at (0) days of storage. The L* values recorded after 120 days of storage varied from 27.51 to 30.20 in treated samples compared to L value of 27.03 in control samples. Maximum L* value was observed in samples pretreated with T₇ solution.

The untreated samples had a* value of 22.81 at (0) days of storage whereas treated samples have a* values of 23.01 to 25.23. The a* values decreased during storage. The a* values recorded after 120 days of storage varied from 20.52 to 23.61 in treated samples compared to a* value of 20.15 in control samples. Maximum a* value of 23.61 was observed in samples pretreated with T₇ solution. Maximum a* value of 25.23 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had b* value of 12.50, whereas treated samples have b* values of 12.62 to 13.44. Maximum b* value of 13.44 was recorded in samples pretreated with T₇ solution at (0) days of storage. The b* values recorded after 120 days of storage varied from 11.71 to 12.41 in treated samples compared to b* value of 11.69 in control samples. Maximum b* value was observed in samples pretreated with T₇ solution.

The untreated samples had (c) value of 26.10, whereas treated samples have (c) values of 26.24 to 28.59. Maximum (c) value of 28.59 was recorded in samples pretreated with T₇ solution at (0) days of storage. The (c) values decreased during storage. The (c) values recorded after 120 days of storage varied from 23.63 to 23.67 in treated samples compared to (c) value of 23.30 in control samples. Maximum (c) value was observed in samples pretreated with T₇ solution.

The untreated samples had (h) value of 28.70 which is found at par with samples pretreated with T₁ solution, whereas treated samples have h values of 28.00 to 28.70. Maximum (h) value of 30.10 was recorded in untreated sample at 120 days of storage. The (h) values recorded after 120 days of storage varied from

27.70 to 29.70 in treated samples compared to (h) value of 30.10 in control samples.

The untreated samples had (ΔE) value of 0.000, whereas treated samples have (ΔE) values of 0.418 to 3.863 at (0) days of storage. The (ΔE) values recorded after 120 days of storage varied from 0.606 to 4.748 in treated samples compared to (ΔE) value of 0.000 in control samples. Maximum (ΔE) value of 4.748 was recorded in samples pretreated with T_7 solution at 120 days of storage. Maximum (ΔE) value was observed in samples pretreated with T_7 solution.

4.3 Experiment No. 2: Effect of pre-treatments mechanical drying temperatures and storage period on quality of chillies (Kashmir Long-1)

4.3.1 Physico-chemical characteristics of dried chilli

4.3.1.1 Moisture content (% db)

Effect of pre-treatments, mechanical drying temperatures and storage period on moisture (% db) of chilli samples is depicted in Table 10.

The initial moisture content of fresh chillies was 80.68% wb and 418.53% db. During mechanical drying operation there was reduction in moisture content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments, drying temperatures and storage period. At the completion of drying process, the moisture content of chilli samples dried at 45°C at 0 days of storage was significantly higher than samples dried at 55° and 65 °C in all treatments. The moisture content recorded in chilli samples dried at 45°C without any pre-treatment was maximum 11.10% db where as the moisture content of pre-treated samples varied from 10.15 to 10.94% db. Minimum moisture content (10.15% db) was recorded in samples dried by using T_7 as pre-treatment solution followed by 10.27% db in samples pretreated with T_6 solution.

The moisture content of chilli samples at the completion of mechanical drying at 55°C was maximum (10.22% db) in control samples and a lower values

of 9.09 to 10.06% db was recorded in pre-treated samples. Minimum moisture (9.09% db) was recorded in samples which were dried after using T₇ as pre-treatment followed by 9.27% db in samples dried using T₆ as pretreatment.

The moisture content of chilli samples at completion of drying at 65°C (at 0 days of storage) was maximum (9.87% db) in control samples and a lower value of 8.72 to 9.70% db was recorded in pre-treated samples. Minimum moisture (8.72% db) was recorded in samples which were dried after using T₇ as pre-treatment followed by 8.90% db in samples pretreated with T₆ solution.

The moisture content of chilli samples increased during storage significantly ($p \leq 0.05$) in all treatments. Higher mean moisture content values during 120 days of storage were observed in chilli samples dried at 45°C (11.29% db) compared to chilli dried at 55°C (10.44% db) and lower values in chilli samples dried at 65°C (10.04% db), respectively.

The mean moisture content of chilli samples dried at 45°C after 30, 60, 90 and 120 days of storage were 11.15, 11.45, 11.58, 11.67% db compared to the lower values of 10.33, 10.58, 10.78, 10.87% db in samples dried at 55°C and still lower values of 9.93, 10.17, 10.36, 10.45% db in samples dried at 65°C, irrespective of pretreatments.

Irrespective of drying methods and storage periods the untreated samples possessed over all maximum mean moisture content (11.05% db) compared to lower values (10.16 to 10.90% db) in pretreated samples. Minimum moisture content 10.16 and 10.32% db was recorded in samples pre-treated with T₇ and T₆ solution respectively.

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant increase in moisture content during 120 days of storage. The over all moisture content recorded increased from 9.86% db at 0 days of storage to a maximum value of 10.99% db at end of 120 days of storage.

Table 10 : Effect of pretreatments, mechanical drying temperatures and storage period on moisture (% db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]																		Overall Mean	
	45°C						55°C						65°C							
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean		
T ₀	11.10	11.55	11.84	11.94	12.05	11.69	10.22	10.75	11.08	11.23	11.33	10.92	9.87	10.38	10.70	10.84	10.94	10.54	11.05	
T ₁	10.94	11.43	11.66	11.84	11.94	11.56	10.06	10.63	10.95	11.05	11.19	10.77	9.70	10.25	10.55	10.65	10.78	10.38	10.90	
T ₂	10.79	11.45	11.75	11.86	11.96	11.56	9.99	10.58	10.90	11.03	11.13	10.72	9.54	10.10	10.41	10.54	10.63	10.24	10.84	
T ₃	10.69	11.19	11.53	11.62	11.72	11.35	9.78	10.40	10.48	10.63	10.72	10.40	9.41	10.00	10.08	10.22	10.31	10.00	10.58	
T ₄	10.60	11.13	11.46	11.59	11.67	11.29	9.59	10.31	10.04	10.42	10.51	10.17	9.24	9.93	9.68	10.04	10.13	9.80	10.42	
T ₅	10.41	11.01	11.32	11.45	11.55	11.14	9.42	10.10	10.50	10.72	10.81	10.31	9.06	9.71	10.09	10.31	10.40	9.91	10.45	
T ₆	10.27	10.79	11.11	11.23	11.33	10.94	9.27	10.00	10.42	10.66	10.75	10.21	8.90	9.60	10.00	10.23	10.31	9.80	10.32	
T ₇	10.15	10.66	10.97	11.08	11.17	10.81	9.09	9.85	10.27	10.47	10.56	10.05	8.72	9.45	9.85	10.05	10.13	9.64	10.16	
Mean	10.62	11.15	11.45	11.58	11.67	11.29	9.68	10.33	10.58	10.78	10.87	10.44	9.30	9.93	10.17	10.36	10.45	10.04		
Storage mean	9.86	10.46	10.73	10.90	10.99															

C.D(p≤0.05)

Treatment (T)	=	0.203
Storage (S)	=	0.262
Drying Temp's (DT)	=	0.690
T x S	=	0.454
T x DT	=	N.S
S x DT	=	N.S
T x S x DT	=	N.S

4.3.1.2 Ascorbic acid (mg/ 100 g db)

Effect of pre-treatments, mechanical drying temperatures and storage period on ascorbic acid content (mg/ 100 g db) of chilli samples is depicted in Table 11.

The initial ascorbic acid content of fresh chillies was 49.4 mg/100g (db). During mechanical drying operation there was reduction in ascorbic acid content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments, temperatures of drying and storage period. At the completion of drying process, the ascorbic acid content of chilli samples dried at 45°C at 0 days of storage was significantly higher than samples dried at 55°C or 65 °C in all treatments. The ascorbic acid content of pre treated samples dried at 45°C varied from 53.21 to 55.51 mg/100g (db) at (0) days of storage. However control samples recorded the minimum ascorbic acid content of 53.20 mg/100 g (db). The maximum ascorbic acid content of 55.51 mg/100g (db) was recorded in chilli samples dried at 45°C using pre-treatment T₇, followed 55.21 mg/100g (db) in samples pretreated with T₆ solution.

The pretreated chilli samples dried at 55°C had ascorbic acid content in range of 49.12 to 51.12 mg/100g db and control samples recorded 49.07 mg/100g (db) ascorbic acid. The chilli samples dried at 55°C at (0) days of storage using pre-treatment T₇ had a maximum ascorbic acid content of 51.12 mg/100g (db) followed by 50.87 mg/100g (db) in samples pretreated with T₆ solution.

The ascorbic acid content of pretreated samples dried at 65°C ranged from 40.95 to 42.65 mg/100g (db) and control samples recorded 40.95 mg/100g (db) ascorbic acid at (0) days storage. The chilli samples dried at 65°C at 0 days of storage using pre-treatment T₇ had a maximum ascorbic acid of 42.65 mg/100g db followed by T₆ (42.44 mg/100g db).

Table-11 : Effect of pretreatments, mechanical drying temperatures and storage period on ascorbic acid (mg/100 g db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]																		Overall Mean
	45°C						55°C						65°C						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
T ₀	53.20	52.85	52.43	51.55	51.14	52.23	49.07	48.79	48.44	47.59	47.23	48.23	40.95	40.70	40.41	39.70	39.37	40.23	46.88
T ₁	53.21	52.94	52.54	51.64	51.19	52.30	49.12	48.84	48.49	47.63	47.24	48.27	40.95	40.71	40.41	39.70	39.40	40.23	46.91
T ₂	53.59	53.24	52.86	51.94	51.55	52.64	49.43	49.16	48.69	47.87	47.51	48.53	41.24	41.00	40.62	39.93	39.62	40.48	47.16
T ₃	54.01	53.55	53.17	52.16	51.89	52.96	49.77	49.43	48.81	47.99	47.75	48.75	41.53	41.24	40.73	40.04	39.84	40.68	47.44
T ₄	54.02	53.66	53.26	52.36	51.96	53.05	49.83	49.54	49.18	48.38	48.00	48.99	41.58	41.33	41.03	40.36	40.04	40.87	47.62
T ₅	54.15	53.85	53.46	52.64	52.13	53.25	49.90	49.66	49.34	48.63	48.15	49.14	41.64	41.43	41.16	40.56	40.16	40.99	47.77
T ₆	55.21	54.83	54.43	53.39	53.16	54.21	50.87	50.62	50.30	49.39	49.17	50.07	42.44	42.22	41.95	41.19	41.00	41.76	48.66
T ₇	55.51	55.17	54.77	53.84	53.35	54.53	51.12	50.92	50.61	49.79	49.34	50.36	42.65	42.47	42.20	41.52	41.14	42.00	48.94
Mean	53.88	53.53	53.14	52.20	51.81	52.91	49.62	49.41	49.10	48.28	47.92	48.87	41.40	41.21	40.95	40.26	39.96	40.76	
Storage mean	48.30	48.05	47.73	46.91	46.56														

C.D(p≤0.05)

Treatment (T)	=	1.728
Storage (S)	=	0.019
Drying Temp.s (DT)	=	0.174
T x S	=	NS
T x DT	=	N.S
S x DT	=	N.S
T x S x DT	=	0.014

Higher mean ascorbic acid values at all sampling dates were observed in chilli samples dried at 45°C (52.91 mg/100g db) compared to chilli dried at 55°C (48.87 mg/100g db) and chilli samples dried at 65°C (40.76 mg/100g db) , respectively.

The ascorbic acid content of chilli samples decreased significantly during storage in all treatments. The mean ascorbic acid of chilli dried at 45°, 55° and 65°C at 30, 60, 90 and 120 days of storage were 53.53, 53.14, 52.20, 51.81 mg/100g db compared to the lower values of 49.41, 49.10, 48.28, 47.92 mg/100g db and 41.21, 40.95, 40.26, 39.96 mg/100g db, irrespective of treatments.

Irrespective of drying methods and storage period the pre-treatment T₇ samples possessed maximum mean ascorbic acid content of (48.94 mg/100g db) and minimum ascorbic acid content of 46.88 mg/100g db was recorded in control samples.

Irrespective of pre-treatments and drying methods the chilli samples exhibited non-significant decrease in ascorbic acid during 120 days of storage. The ascorbic acid content decreased from 48.30 mg/100g db at 0 days of storage to a minimum value of 46.56 mg/100g db at end of 120 days of storage.

4.3.1.3 Capsaicin (% db)

Effect of pre-treatments, mechanical drying temperatures and storage period on capsaicin (% db) of chilli samples is depicted in Table 12.

The initial capsaicin content of fresh chillies was 0.38% db. During mechanical drying operation there was reduction in capsaicin content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments, temperatures of drying and storage period. At the completion of drying process, the capsaicin content of chilli samples dried at 45°C at 0 days of storage were significantly higher than samples dried at 55° or 65 °C in all treatments. The capsaicin content of pre-treated samples dried at 45°C varied from 0.954 to 1.094% (db) at (0) days of storage. The control samples recorded the

capsaicin content of 0.922% (db). The capsaicin content recorded in chilli samples dried at 45°C using pre-treatment T₇ was maximum 1.094% (db) followed 1.082% (db) in samples pretreated with T₆ solution.

The pretreated chilli samples dried at 55°C had capsaicin content in range of 0.724 to 0.775% db at (0) days of storage and control samples recorded 0.716% (db) capsaicin content. The chilli samples dried at 55°C at 0 days of storage using pre-treatment T₇ had a maximum capsaicin content of 0.775% db followed by 0.766% db in samples pretreated with T₆ solution.

The capsaicin content of pretreated samples dried at 65°C ranged from 0.629 to 0.716% db at (0) days of storage and control samples recorded 0.615% db capsaicin content. The chilli samples dried at 65°C at 0 days of storage using pre-treatment T₇ had a maximum capsaicin content of 0.716% db followed 0.678% db in samples pretreated with T₆ solution.

Higher mean capsaicin content values at all sampling dates were observed in chilli samples dried at 45°C (0.940% db) compared to chilli dried at 55°C (0.665% db) and chilli samples dried at 65°C (0.592% db), respectively.

The capsaicin content of chilli samples decreased significantly during storage in all treatments. The mean capsaicin content of chilli samples dried at 45°, 55° and 65°C at 30, 60, 90 and 120 days of storage were 0.976, 0.931, 0.898, 0.873% db compared to the lower values of 0.705, 0.667, 0.634, 0.573% db and 0.621, 0.587, 0.557, 0.538% db, respectively, irrespective of treatments.

Irrespective of drying temperatures and storage periods the samples pretreated with T₇ possessed maximum mean capsaicin content (0.786% db) compared to minimum capsaicin content of 0.671% db recorded in control samples.

Irrespective of pre-treatments and drying temperatures the chilli samples exhibited non-significant decrease in capsaicin content during 120 days of storage. The capsaicin content recorded decreased from 0.807% db at 0 days of storage to a minimum value of 0.649% db at end of 120 days of storage.

Table-12: Effect of pretreatments, mechanical drying temperatures and storage period on capsaicin (% db)of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]																		Overall Mean	
	45°C						55°C						65°C							
	0	30)	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean		
T ₀	0.922	0.866	0.834	0.797	0.792	0.842	0.716	0.673	0.624	0.601	0.549	0.636	0.615	0.578	0.536	0.491	0.457	0.536	0.671	
T ₁	0.954	0.898	0.865	0.826	0.815	0.872	0.724	0.682	0.634	0.620	0.552	0.642	0.629	0.593	0.551	0.493	0.481	0.550	0.688	
T ₂	0.987	0.920	0.874	0.857	0.845	0.897	0.734	0.684	0.645	0.627	0.560	0.650	0.636	0.593	0.559	0.526	0.527	0.568	0.705	
T ₃	1.032	0.988	0.938	0.906	0.876	0.948	0.739	0.704	0.671	0.637	0.560	0.662	0.645	0.618	0.585	0.566	0.547	0.592	0.734	
T ₄	1.052	1.006	0.954	0.925	0.899	0.967	0.745	0.708	0.673	0.641	0.573	0.668	0.649	0.621	0.586	0.570	0.554	0.596	0.744	
T ₅	1.064	1.029	0.974	0.936	0.901	0.981	0.757	0.714	0.686	0.645	0.584	0.677	0.663	0.642	0.608	0.585	0.563	0.612	0.756	
T ₆	1.082	1.041	0.998	0.964	0.929	1.003	0.766	0.733	0.694	0.648	0.597	0.688	0.678	0.654	0.627	0.606	0.584	0.630	0.774	
T ₇	1.094	1.054	1.013	0.969	0.929	1.012	0.775	0.739	0.709	0.655	0.610	0.698	0.716	0.670	0.644	0.617	0.591	0.648	0.786	
Mean	1.023	0.976	0.931	0.898	0.873	0.940	0.745	0.705	0.667	0.634	0.573	0.665	0.654	0.621	0.587	0.557	0.538	0.592		
Storage mean	0.807	0.767	0.728	0.696	0.649															

C.D(p≤0.05)

Treatment (T)	=	0.025
Storage (S)	=	0.020
Drying Temp.s (DT)	=	0.015
T x S	=	NS
T x DT	=	N.S
S x DT	=	N.S
T x S x DT	=	0.097

4.3.1.4 Capsanthin (ASTA units)

Effect of pre-treatments, mechanical drying temperatures and storage periods on capsanthin content (ASTA units) of chilli samples is depicted in Table 13.

The initial capsanthin content of fresh chillies was 98.378 ASTA units. During mechanical drying operation there was increase in capsanthin content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments and storage period. At the completion of drying process, the capsanthin content of chilli samples dried at 45°C at (0) days of storage was significantly higher than samples dried at 55° and 65°C in all treatments. The capsanthin content of pre treated samples dried at 45°C varied from 126.93 to 127.52 ASTA units at (0) days of storage. However control samples recorded the capsanthin content of 126.73 ASTA units. The capsanthin content recorded in chilli samples dried at 45°C using pre-treatment T₇ was maximum 127.72 ASTA units at (0) days of storage followed by 127.52 ASTA units in samples pretreated with T₆ solution.

The pretreated chilli samples dried at 55°C had capsanthin content in range of 126.75 to 127.57 ASTA units at (0) days of storage whereas, control samples recorded capsanthin content of 126.57 ASTA units at 0 days of storage. The chilli samples dried at 55°C at 0 days of storage using pre-treatment T₇ had a maximum capsanthin content of 127.57 ASTA units followed by 127.32 ASTA units in T₆ pretreated samples.

The capsanthin content of pretreated chilli samples dried at 65°C ranged from 126.52 to 127.44 ASTA units at (0) days of storage whereas, control samples recorded capsanthin content of 126.32 ASTA units. The chilli samples dried at 65°C using pre-treatment T₇ had a maximum capsanthin content of 127.44 ASTA units at (0) days of storage followed by samples pretreated with T₆ solution as 127.21 ASTA units. Higher mean capsanthin content values at all sampling dates were observed in chilli samples dried at 45°C (126.44 ASTA units) compared to chilli samples dried at 55°C (126.21 ASTA units) and chilli samples dried at 65°C (125.97 ASTA units), respectively.

Table-13 : Effect of pretreatments, mechanical drying temperatures and storage period on capsanthin(ASTA units db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]																		Overall Mean	
	45°C						55°C						65°C							
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean		
T ₀	126.73	126.58	126.06	125.47	124.42	125.85	126.57	126.40	125.86	125.27	124.22	125.66	126.32	126.07	125.51	124.86	123.83	125.32	125.61	
T ₁	126.93	126.82	126.22	125.64	124.64	126.05	126.75	126.62	126.05	125.43	124.42	125.86	126.52	126.31	125.69	125.12	124.09	125.55	125.82	
T ₂	127.16	127.08	126.29	125.77	124.72	126.20	126.89	126.77	126.08	125.55	124.49	125.96	126.67	126.65	126.10	125.45	124.42	125.86	126.01	
T ₃	127.22	127.17	126.37	125.89	124.84	126.30	127.03	126.96	126.16	125.61	124.56	126.06	126.85	126.66	126.15	125.48	124.44	125.92	126.09	
T ₄	127.30	127.18	126.55	125.93	124.88	126.37	127.07	127.00	126.23	125.81	124.74	126.17	126.99	126.82	126.28	125.63	124.58	126.06	126.20	
T ₅	127.42	127.36	126.89	126.35	125.29	126.66	127.23	127.20	126.65	126.12	125.04	126.45	127.11	126.94	126.43	125.70	124.64	126.17	126.43	
T ₆	127.52	127.50	127.08	126.56	125.50	126.83	127.32	127.30	126.86	126.33	125.27	126.62	127.21	127.14	126.59	125.98	124.93	126.37	126.61	
T ₇	127.72	127.70	127.38	126.87	125.81	127.09	127.57	127.52	127.13	126.62	125.56	126.88	127.44	127.28	126.74	126.11	125.06	126.53	126.83	
Mean	127.25	127.17	126.60	126.06	125.13	126.44	127.05	126.97	126.38	125.84	124.79	126.21	126.89	126.73	126.19	125.54	124.50	125.97		
Storage mean	127.06	126.96	126.39	125.81	124.81															

C.D(p≤0.05)

Treatment (T)	=	0.201
Storage (S)	=	0.003
Drying Temp.s (DT)	=	NS
T x S	=	NS
T x DT	=	N.S
S x DT	=	N.S
T x S x DT	=	0.012

The capsanthin content of chilli samples decreased significantly during storage in all treatments. The mean capsanthin content of chilli samples dried at 45°, 55° and 65°C irrespective of pretreatments at 30, 60, 90 and 120 days of storage were 127.17, 126.60, 126.06, 125.13 ASTA units compared to the lower values of 126.97, 126.38, 125.84, 124.79 ASTA units and 126.73, 126.19, 125.54, 1224.50 ASTA units, irrespectively.

Irrespective of drying temperatures and storage periods the chilli samples dried using pre-treatment T₇ possessed overall maximum mean capsanthin content (126.83 ASTA units) followed by 126.61ASTA units in T₆ treated samples whereas, minimum capsanthin content of 125.61 ASTA units was recorded in control samples.

Irrespective of pre-treatments and drying temperatures the chilli samples exhibited non-significant decrease in capsanthin content during 120 days of storage. The capsanthin content decreased from 127.06 ASTA units at 0 days of storage to a minimum value of 124.81 ASTA units at end of 120 days of storage.

4.3.1.5 Reducing Sugar (% db)

Effect of pre-treatments, mechanical drying temperatures and storage periods on reducing sugar content (% db) of chilli samples is depicted in Table 14.

The initial reducing sugar content of fresh chillies was 0.648% (db). During mechanical drying operation there was reduction in reducing sugar content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments and temperatures of drying. At the completion of drying process, the reducing sugar content of chilli samples dried at 45°C at 0 days of storage was significantly higher than samples dried at 55 ° and 65 °C samples in all treatments. The reducing sugar content of pre treated samples dried at 45⁰C at (0) days of storage varied from 0.599 to 0.614% (db). However control samples recorded the

Table-14 : Effect of pretreatments, mechanical drying temperatures and storage period on reducing sugars(% db) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]																		Overall Mean
	45°C						55°C						65°C						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
T ₀	0.594	0.553	0.526	0.461	0.425	0.512	0.541	0.504	0.480	0.421	0.386	0.467	0.510	0.476	0.452	0.397	0.364	0.441	0.473
T ₁	0.599	0.558	0.529	0.473	0.430	0.518	0.541	0.505	0.479	0.428	0.388	0.468	0.511	0.476	0.452	0.404	0.366	0.442	0.476
T ₂	0.602	0.562	0.533	0.477	0.432	0.522	0.541	0.505	0.479	0.429	0.388	0.468	0.511	0.477	0.452	0.404	0.366	0.442	0.477
T ₃	0.605	0.565	0.536	0.479	0.432	0.523	0.541	0.506	0.479	0.428	0.388	0.469	0.511	0.477	0.453	0.404	0.366	0.443	0.478
T ₄	0.610	0.570	0.542	0.485	0.437	0.529	0.542	0.507	0.480	0.431	0.389	0.470	0.512	0.479	0.454	0.406	0.367	0.444	0.481
T ₅	0.611	0.571	0.544	0.487	0.437	0.530	0.543	0.508	0.484	0.434	0.390	0.472	0.512	0.479	0.457	0.409	0.368	0.445	0.482
T ₆	0.614	0.574	0.546	0.489	0.441	0.533	0.543	0.509	0.485	0.435	0.391	0.473	0.513	0.480	0.458	0.410	0.369	0.446	0.484
T ₇	0.614	0.574	0.547	0.491	0.441	0.534	0.543	0.509	0.486	0.436	0.391	0.473	0.513	0.480	0.458	0.411	0.369	0.447	0.484
Mean	0.606	0.566	0.538	0.480	0.434	0.525	0.542	0.507	0.481	0.430	0.389	0.470	0.512	0.478	0.454	0.406	0.367	0.444	
Storage mean	0.556	0.521	0.497	0.446	0.400														

C.D(p≤0.05)

Treatment (T)	=	0.062
Storage (S)	=	NS
Drying Temp.s (DM)	=	0.010
T x S	=	NS
T x DT	=	0.021
S x DT	=	N.S
T x S x DT	=	NS

reducing sugar content of 0.594% (db). The reducing sugar content recorded in chilli samples dried at 45°C using pre-treatment T₇ was maximum 0.614% (db) at par with samples pretreated with T₆ solution at (0) days of storage.

The pretreated chilli samples dried at 55°C at (0) days of storage had reducing sugar content in the range of 0.541 to 0.543% db and control samples recorded 0.541% db reducing sugar content. The chilli samples dried at 55°C at 0 days of storage using pre-treatment T₇ had a maximum reducing sugar content of 0.543% (db) at par with T₆ pretreated samples.

The reducing sugar content of pretreated samples dried at 65°C at (0) days of storage ranges from 0.511 to 0.513% db whereas, control samples recorded reducing sugar content of 0.510%. The chilli samples dried at 65°C at 0 days of storage using pre-treatment T₇ had a maximum reducing sugar content of 0.513% db at par with T₆ pretreated samples.

Higher mean reducing sugar content values at all sampling dates were observed in chilli samples dried at 45°C (0.525% db) compared to chilli dried at 55°C (0.470%db) and chilli dried at 65°C (0.444% db) , respectively, irrespective of pretreatments and storage periods.

The reducing sugar content of chilli samples decreased significantly during storage in all samples. The mean reducing sugar content of chilli samples dried at 45°, 55° and 65°C at 30, 60, 90 and 120 days of storage were 0.566, 0.538, 0.480, 0.434% db compared to the lower values of 0.507, 0.481, 0.430, 0.389% db and 0.478, 0.454, 0.406, 0.367% db, respectively, irrespective of treatments.

Irrespective of drying temperature and storage periods the samples prepared using T₇ solution possessed maximum mean reducing sugar content (0.484% db) compared to minimum reducing sugar content of 0.473% db recorded in control samples.

Irrespective of pre-treatments and drying methods the chilli samples exhibited significant decrease in reducing sugar content during 120 days of

storage. The reducing sugar content recorded decreased from 0.556% db at 0 days of storage to a minimum value of 0.400% db at end of 120 days of storage.

4.3.1.6 Non Enzymatic Browning

Effect of pre-treatments, mechanical drying temperatures and storage period on non-enzymatic browning values of chilli samples is depicted in Table 15.

During mechanical drying operation there was increase in non-enzymatic browning of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments and temperatures of drying. At the completion of drying process, the non-enzymatic browning values of chilli samples dried at 65°C at 0 days of storage were significantly higher than samples dried at 45° and 55 °C in all treatments. The non-enzymatic browning values recorded in chilli samples dried at 45°C without any pre-treatment was maximum 0.241 where as the non-enzymatic browning values of pre-treated samples varied from 0.111 to 0.239. Minimum non-enzymatic browning value of 0.111 was recorded in samples dried by using T₇ as pre-treatment solution followed by 0.120 in samples pretreated with T₆ solution.

The non-enzymatic browning value of chilli samples at the completion of drying at 55°C was maximum (0.344) in control samples and a lower value of 0.298 to 0.343 were recorded in pre-treated samples at (0) days of storage. Minimum non-enzymatic browning value (0.298) was recorded in samples which were dried after using T₇ solution as pre-treatment followed by 0.299 in T₆ pretreated samples. The non-enzymatic browning of chilli samples at the completion of drying at 65°C was maximum (0.504) in control samples and a lower value of 0.374 to 0.502 was recorded in pre-treated samples at (0) days of storage. Minimum non-enzymatic browning (0.374) was recorded in samples which were dried after using T₇ as pre-treatment followed by 0.461 in T₆ pretreated samples.

Table-15 : Effect of pretreatments, mechanical drying temperatures and storage period on non-enzymatic browning values(OD at 420 nm) of whole chillies (Kashmir Long-1)

Treatment	Storage [Days]																		Overall Mean
	45°C						55°C						65°C						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
T ₀	0.241	0.326	0.345	0.452	0.481	0.369	0.344	0.387	0.462	0.533	0.608	0.467	0.504	0.513	0.550	0.600	0.680	0.569	0.469
T ₁	0.239	0.325	0.344	0.451	0.480	0.368	0.343	0.386	0.446	0.517	0.600	0.458	0.502	0.512	0.549	0.600	0.680	0.568	0.465
T ₂	0.219	0.303	0.323	0.426	0.456	0.345	0.320	0.363	0.421	0.489	0.564	0.431	0.501	0.510	0.549	0.598	0.677	0.567	0.448
T ₃	0.217	0.301	0.321	0.425	0.456	0.344	0.318	0.361	0.418	0.486	0.562	0.429	0.494	0.500	0.536	0.588	0.667	0.555	0.435
T ₄	0.207	0.290	0.311	0.413	0.444	0.333	0.307	0.350	0.407	0.474	0.549	0.417	0.488	0.498	0.525	0.583	0.661	0.553	0.443
T ₅	0.197	0.281	0.301	0.403	0.433	0.323	0.301	0.340	0.400	0.464	0.544	0.409	0.475	0.486	0.525	0.572	0.653	0.524	0.425
T ₆	0.120	0.191	0.212	0.291	0.384	0.239	0.299	0.339	0.400	0.462	0.542	0.408	0.461	0.468	0.512	0.541	0.640	0.522	0.390
T ₇	0.111	0.184	0.203	0.289	0.363	0.230	0.298	0.338	0.397	0.452	0.542	0.406	0.374	0.382	0.407	0.498	0.580	0.448	0.362
Mean	0.194	0.275	0.295	0.394	0.437	0.319	0.316	0.358	0.419	0.485	0.564	0.428	0.475	0.484	0.519	0.573	0.655	0.541	
Storage mean	0.328	0.372	0.411	0.484	0.552														

C.D(p≤0.05)

Treatment (T)	=	0.062
Storage (S)	=	NS
Drying Temp.s (DT)	=	0.034
T x S	=	NS
T x DT	=	NS
S x DT	=	0.211
T x S x DT	=	NS

Irrespective of pre treatments and storage days the mean non-enzymatic browning values during 120 days of storage were observed in chilli samples dried at 45°C (0.319) compared to higher values in chilli samples dried at 55°C (0.428) and chilli samples dried at 65°C (0.541) , respectively.

The non-enzymatic browning of chilli samples increased during storage significantly in all samples. The mean non-enzymatic browning values of chilli samples dried at 45, 55 and 65°C at 30, 60, 90 and 120 days of storage were 0.275, 0.295, 0.394, 0.437 compared to the lower values of 0.358, 0.419, 0.485, 0.564 and 0.484, 0.519, 0.573, 0.655.

Irrespective of drying temperatures and storage periods the untreated samples possessed over all maximum mean non-enzymatic browning value (0.469) compared to lower values (0.362 to 0.465) in treated samples. Minimum non-enzymatic browning values of 0.362 and 0.390 were recorded in samples pre-treated with T₇ and T₆ solution respectively.

Irrespective of pre-treatments and drying temperatures the chilli samples exhibited non-significant increase in non-enzymatic browning during 120 days of storage. The over all non-enzymatic browning values recorded increased from 0.328 at 0 days of storage to a maximum value of 0.552 at end of 120 days of storage.

4.3.1.7 Colour values (L*, a*, b*, c, h (ΔE)) in chilli dried at 45°C.

The colour parameters of chilli samples after mechanical drying at 45°C and during storage as influenced by pretreatment applications are presented in Table 16. On day (0) all the treated samples had highest L*, a*, b*, c values which significantly ($p \leq 0.05$) decreased with storage period, while as, h and (ΔE) value had significantly increased. At (0) days of storage the untreated samples had L* value of 28.93, whereas treated samples have L* values of 29.28 to 31.81. where as maximum L* value of 31.81 was recorded in samples pretreated with T₇ solution at (0) days of storage. The L* values recorded after 120 days of storage

varied from 27.73 to 30.44 in treated samples compared to L^* value of 27.25 in control samples. Maximum L^* value was observed in samples pretreated with T_7 solution.

At (0) days of storage the untreated samples had a^* value of 23.46, whereas treated samples have a^* values of 23.67 to 25.95, where as maximum a^* value of 25.95 was recorded in samples pretreated with T_7 solution at (0) days of storage. The a^* values recorded after 120 days of storage varied from 21.70 to 24.97 in treated samples compared to a^* value of 12.67 in control samples. Maximum a^* value was observed in samples pretreated with T_7 solution.

The untreated samples had b^* value of 13.55, whereas treated samples have b^* values of 13.68 to 14.57. Maximum b^* value of 14.57 was recorded in samples pretreated with T_7 solution at (0) days of storage. The b^* values recorded after 120 days of storage varied from 12.69 to 13.45 in treated samples compared to b^* value of 12.67 in control samples. Maximum b^* value was observed in samples pretreated with T_7 solution.

The untreated samples had (c) value of 27.09 at (0) days of storage, whereas treated samples have (c) values of 27.34 to 29.76. Maximum c value of 29.76 was recorded in samples pretreated with T_7 solution at (0) days of storage. The (c) values recorded after 120 days of storage varied from 25.09 to 28.36 in treated samples compared to (c) value of 24.79 in control samples. Maximum (c) value was observed in samples pretreated with T_7 solution.

At (0) days of storage the untreated samples had (h) value of 30.00 which is found at par with samples pretreated with T_1 solution, whereas treated samples have (h) values of 29.30 to 30.00. Maximum h value of 30.70 was recorded in control at 120 days of storage. The (h) values recorded after 120 days of storage varied from 28.30 to 30.10 in treated samples compared to (h) value of 30.70 in control samples. Maximum (h) value was observed in control samples.

Table 16 : Effect of pretreatments, mechanical drying method at 45°C and storage period on L*, a*, b* in of chillies (Kashmir Long-1)

Parameter	Storage (days)	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
L*	0	28.93	29.28	29.66	30.06	30.41	30.76	31.12	31.81	30.25
	30	28.51	28.89	29.28	29.68	30.06	30.44	30.81	31.47	29.89
	60	28.08	28.49	28.89	29.3	29.68	30.1	30.49	31.1	29.52
	90	27.65	28.12	28.51	28.96	29.34	29.79	30.18	30.78	29.17
	120	27.25	27.73	28.14	28.54	28.99	29.47	29.88	30.44	28.81
	Mean	28.08	28.5	28.89	29.31	29.7	30.11	30.5	31.12	
a*	0	23.46	23.67	24.09	24.46	24.84	25.24	25.64	25.95	24.67
	30	22.94	23.19	23.61	24.02	24.42	24.82	25.28	25.71	24.25
	60	22.4	22.67	23.1	23.59	23.97	24.36	24.91	25.44	23.8
	90	21.83	22.21	22.59	23.2	23.56	23.95	24.54	25.21	23.39
	120	21.31	21.7	22.11	22.66	23.13	23.52	24.18	24.97	22.95
	Mean	22.39	22.69	23.1	23.59	23.98	24.38	24.91	25.46	
b*	0	13.55	13.68	13.83	13.92	14.06	14.24	14.4	14.57	14.03
	30	13.33	13.43	13.57	13.67	13.8	13.97	14.11	14.29	13.77
	60	13.11	13.18	13.3	13.42	13.53	13.69	13.83	13.99	13.51
	90	12.88	12.94	13.04	13.2	13.28	13.43	13.54	13.73	13.26
	120	12.67	12.69	12.79	12.92	13.03	13.16	13.27	13.45	13
	Mean	13.11	13.19	13.31	13.43	13.54	13.7	13.83	14.01	
c*	0	27.09	27.34	27.78	28.14	28.54	28.98	29.41	29.76	28.38
	30	26.53	26.8	27.23	27.64	28.05	28.48	28.95	29.41	27.89
	60	25.95	26.22	26.66	27.14	27.52	27.94	28.49	29.03	27.37
	90	25.35	25.7	26.08	26.69	27.04	27.46	28.03	28.71	26.88
	120	24.79	25.09	25.54	26.08	26.55	26.95	27.58	28.36	26.37
	Mean	25.942	26.23	26.658	27.138	27.54	27.962	28.492	29.054	
h	0	30	30	29.9	29.6	29.5	29.4	29.3	29.3	29.63
	30	30.2	30.1	29.9	29.6	29.5	29.4	29.2	29.1	29.63
	60	30.3	30.2	29.9	29.6	29.4	29.3	29	28.8	29.56
	90	30.5	30.2	30	29.6	29.4	29.3	28.9	28.6	29.56
	120	30.7	30.1	30	29.7	29.4	29.2	28.8	28.3	29.53
	Mean	30.34	30.12	29.94	29.62	29.44	29.32	29.04	28.82	
ΔE	0	0	0.42	1.00	1.54	2.08	2.64	3.20	3.94	1.86
	30	0	0.46	1.04	1.62	2.19	2.76	3.37	4.16	1.96
	60	0	0.49	1.08	1.73	2.28	2.87	3.55	4.37	2.05
	90	0	0.61	1.15	1.92	2.45	3.06	3.76	4.68	2.21
	120	0	0.62	1.20	1.88	2.54	3.17	3.93	4.91	2.29
	Mean	0	0.52	1.09	1.74	2.31	2.90	3.56	4.41	

C.D (p≤0.05)

Treatment (T) = 0.032
Storage (S) = 0.017
TXS = 0.080

The untreated samples had (ΔE) value of 0.00, whereas treated samples had (ΔE) values of 0.426 to 3.943. The (ΔE) values recorded after 120 days of storage varied from 0.620 to 4.919 in treated samples compared to (ΔE) value of 0.000 in control samples. Maximum (ΔE) value was observed in samples pretreated with T₇ solution. Maximum (ΔE) value of 4.919 was recorded in samples pretreated with T₇ solution at 120 days of storage.

4.3.1.8 Colour values (L*, a*, b*, c, h (ΔE)) in chilli dried at 55°C.

The colour parameters of chilli samples after mechanical drying at 55°C and during storage as influenced by pretreatment applications are presented in Table 17. On day (0) all the treated samples had highest L*, a*, b* and c values which significantly ($p \leq 0.05$) decreased with storage period, while as (h) and (ΔE) value had significantly increased. At (0) days of storage the untreated samples had L* value of 27.39, whereas treated samples have L* values of 27.72 to 30.39. Maximum L* value of 30.39 was recorded in samples pretreated with T₇ solution. The L* values recorded after 120 days of storage varied from 27.05 to 29.96 in treated samples compared to L* value of 26.58 in control samples. Maximum L* value was observed in samples pretreated with T₇ solution.

At (0) days of storage the untreated samples had a* value of 21.14, whereas treated samples have a* values of 21.33 to 23.38, where as maximum a* value of 23.38 was recorded in samples pretreated with T₇ solution. The a* values recorded after 120 days of storage varied from 19.56 to 22.50 in treated samples compared to a* value of 19.20 in control samples. Maximum a* value was observed in samples pretreated with T₇ solution.

At (0) days of storage the untreated samples had b* value of 11.67, whereas treated samples have b* values of 11.78 to 12.42. Maximum b* value of 12.42 was recorded in samples pretreated with T₇ solution. The b* values

Table 17 : Effect of pretreatments, mechanical drying method at 55°C and storage period on L*, a*, b* in of chillies (Kashmir Long-1)

Parameter	Storage (days)	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
L*	0	27.39	27.72	28.08	28.46	28.79	29.12	29.47	30.39	28.68
	30	27.4	27.77	28.14	28.52	28.88	29.25	29.61	30.52	28.76
	60	27.12	27.52	27.9	28.3	28.67	29.07	29.45	30.31	28.54
	90	26.84	27.3	27.67	28.12	28.48	28.92	29.3	30.14	28.34
	120	26.58	27.05	27.46	27.84	28.28	28.75	29.15	29.96	28.13
	Mean	27.07	27.47	27.85	28.25	28.62	29.02	29.4	30.27	
a*	0	21.14	21.33	21.71	22.04	22.38	22.74	23.1	23.38	22.23
	30	20.67	20.89	21.27	21.64	22.01	22.37	22.78	23.17	21.85
	60	20.18	20.43	20.81	21.26	21.6	21.96	22.45	22.92	21.45
	90	19.67	20.02	20.36	20.91	21.23	21.58	22.11	22.72	21.07
	120	19.2	19.56	19.93	20.42	20.84	21.19	21.79	22.5	20.68
	Mean	20.17	20.44	20.82	21.25	21.61	21.97	22.45	22.94	
b*	0	11.67	11.78	11.91	11.99	12.17	12.25	12.37	12.42	12.07
	30	11.54	11.6	11.72	11.9	12.05	12.21	12.35	12.55	11.99
	60	11.37	11.45	11.65	11.86	12	12.14	12.27	12.41	11.89
	90	11.41	11.47	11.55	11.85	11.95	12.11	12.31	12.51	11.89
	120	11.02	11.25	11.33	11.43	11.56	11.67	11.77	11.93	11.5
	Mean	11.4	11.51	11.63	11.81	11.95	12.08	12.21	12.37	
c*	0	24.15	24.37	24.76	25.09	25.47	25.83	26.2	26.47	25.29
	30	23.67	23.89	24.29	24.7	25.09	25.49	25.91	26.35	24.92
	60	23.16	23.42	23.85	24.34	24.71	25.09	25.58	26.06	24.53
	90	22.74	23.07	23.41	24.03	24.36	24.75	25.31	25.94	24.2
	120	22.14	22.56	22.93	23.4	23.83	24.19	24.77	25.47	23.66
	Mean	23.172	23.462	23.848	24.312	24.692	25.07	25.554	26.058	
h	0	28.9	28.9	28.7	28.5	28.5	28.3	28.2	28	28.5
	30	29.2	29	28.9	28.8	28.7	28.6	28.5	28.4	28.76
	60	29.4	29.3	29.2	29.2	29.1	28.9	28.7	28.4	29.03
	90	30.1	29.8	29.6	29.5	29.4	29.3	29.1	28.8	29.45
	120	29.9	29.9	29.6	29.2	29	28.8	28.4	27.9	29.09
	Mean	29.5	29.38	29.2	29.04	28.94	28.78	28.58	28.3	
ΔE	0	0	0.39	0.92	1.43	1.93	2.42	2.94	3.82	1.74
	30	0	1.42	1.76	2.17	2.62	3.12	3.64	4.53	2.41
	60	0	1.38	1.73	2.18	2.66	3.17	3.76	4.67	2.45
	90	0	1.4	1.73	2.25	2.76	3.30	3.91	4.91	2.54
	120	0	1.36	1.73	2.25	2.82	3.38	4.04	5.1	2.59
	Mean	0	1.19	1.57	2.05	2.56	3.08	3.66	4.60	

C.D (p≤0.05)

Treatment (T) = 0.024

Storage (S) = 0.022

TXS = 0.080

recorded after 120 days of storage varied from 11.25 to 11.93 in treated samples compared to b^* value of 11.02 in control samples. Maximum b^* value was observed in samples pretreated with T_7 solution.

At (0) days of storage the untreated samples had (c) value of 24.15, whereas treated samples have (c) values of 24.37 to 26.47 where as maximum c value of 26.47 was recorded in samples pretreated with T_7 solution. The (c) values recorded after 120 days of storage varied from 22.56 to 25.47 in treated samples compared to (c) value of 22.14 in control samples. Maximum (c) value was observed in samples pretreated with T_7 solution. At (0) days of storage the untreated samples had (h) value of 28.90 which is found at par with samples pretreated with T_1 solution, whereas other treated samples have (h) values of 28.00 to 28.90. The (h) values recorded after 120 days of storage varied from 27.90 to 29.90 in treated samples compared to h value of 29.90 in control samples. Maximum (h) value was observed in control samples. Maximum (h) value of 29.90 was recorded in control which is found at par with samples pretreated with T_1 solution at 120 days of storage.

At (0) days of storage the untreated samples had (ΔE) value of 0.00, whereas treated samples have (ΔE) values of 0.396 to 3.821. The (ΔE) values recorded after 120 days of storage varied from 1.361 to 5.100 in treated samples compared to (ΔE) value of 0.000 in control samples. Maximum (ΔE) value was observed in samples pretreated with T_7 solution. Maximum (ΔE) value of 5.100 was recorded in samples pretreated with T_7 solution at 120 days of storage.

4.3.1.9 Colour values (L^* , a^* , b^* , c, h (ΔE)) in chilli dried at 65°C.

The colour parameters of chilli samples after mechanical drying at 65°C and during storage as influenced by pretreatment applications are presented in Table 18. On day (0) all the treated samples had highest L^* , a^* , b^* and c values which significantly ($p \leq 0.05$) decreased with storage period, while as (h) and (ΔE) value had significantly increased. At (0) days of storage the untreated samples had

L* value of 26.92, whereas treated samples have L* values of 27.95 to 29.60. Maximum L* value of 29.60 was recorded in samples pretreated with T₇ solution. The L* values recorded after 120 days of storage varied from 25.80 to 28.33 in treated samples compared to L* value of 25.35 in control samples. Maximum L* value was observed in samples pretreated with T₇ solution.

At (0) days of storage the untreated samples had a* value of 20.33, whereas treated samples have a* values of 20.51 to 23.57, where as maximum a* value of 23.57 was recorded in samples pretreated with T₇ solution at (0) days of storage. The a* values recorded after 120 days of storage varied from 18.81 to 22.68 in treated samples compared to a* value of 18.47 in control samples. Maximum a* value was observed in samples pretreated with T₇ solution.

At (0) days of storage the untreated samples had b* value of 12.25, whereas treated samples have b* values of 12.30 to 13.56. Maximum b* value of 13.56 was recorded in samples pretreated with T₇ solution .The b* values recorded after 120 days of storage varied from 13.82 to 14.97 in treated samples compared to b* value of 13.79 in control samples. Maximum b* value was observed in samples pretreated with T₇ solution. At (0) days of storage the untreated samples had (c) value of 23.74, whereas treated samples had (c) values of 23.97 to 27.19. Maximum (c) value of 27.19 was recorded in samples pretreated with T₇ solution at (0) days of storage. The (c) values recorded after 120 days of storage varied from 23.34 to 27.18 in treated samples compared to (c) value of 23.05 in control samples. Maximum (c) value was observed in samples pretreated with T₇ solution.

At (0) days of storage the untreated samples had (h) value of 31.10, whereas treated samples have (h) values of 29.90 to 31.00, where as maximum (h) value of 31.10 was recorded in control samples. The (h) values recorded after 120 days of storage varied from 33.40 to 36.60 in treated samples compared to (h) value of 36.70 was recorded in control samples. Maximum (h) value was observed in control samples.

Table 18 : Effect of pretreatments, mechanical drying method at 65°C and storage period on L*, a*, b* in of chillies (Kashmir Long-1)

Parameter	Storage (days)	Treatments								Mean
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
L*	0	26.92	27.25	27.6	27.97	28.3	28.62	28.96	29.6	28.15
	30	26.53	26.89	27.24	27.61	27.97	28.32	28.67	29.28	27.81
	60	26.13	26.51	26.88	27.27	27.62	28.01	28.38	28.94	27.47
	90	25.73	26.17	26.53	26.95	27.3	27.72	28.09	28.64	27.14
	120	25.35	25.8	26.19	26.55	26.98	27.43	27.8	28.33	26.8
	Mean	26.13	26.52	26.89	27.27	27.63	28.02	28.38	28.96	
a*	0	20.33	20.51	20.87	21.19	21.52	21.87	22.22	23.57	21.51
	30	19.88	20.09	20.46	20.82	21.16	21.51	21.91	23.36	21.15
	60	19.41	19.65	20.02	20.44	20.77	21.11	21.59	23.11	20.76
	90	18.92	19.25	19.58	20.11	20.42	20.75	21.27	22.9	20.4
	120	18.47	18.81	19.16	19.64	20.04	20.38	20.95	22.68	20.02
	Mean	19.4	19.66	20.02	20.44	20.78	21.13	21.59	23.12	
b*	0	12.25	12.3	12.47	12.54	12.71	12.9	13.01	13.56	12.72
	30	12.6	12.71	12.9	13	13.12	13.25	13.33	13.48	13.05
	60	13.5	13.6	13.73	13.83	13.95	14.1	14.18	14.8	13.96
	90	13.55	13.68	13.81	14.1	14.22	14.28	14.4	15.3	14.17
	120	13.79	13.82	13.91	14.14	14.22	14.35	14.65	14.97	14.23
	Mean	13.14	13.22	13.36	13.52	13.64	13.78	13.91	14.42	
c*	0	23.74	23.92	24.31	24.62	24.99	25.39	25.74	27.19	24.99
	30	23.54	23.77	24.19	24.55	24.9	25.62	25.65	26.97	24.9
	60	23.64	23.9	24.28	24.68	25.02	25.39	25.83	27.44	25.02
	90	23.27	23.62	23.96	24.56	24.88	25.19	25.69	27.54	24.84
	120	23.05	23.34	23.68	24.2	24.57	24.93	25.56	27.18	24.56
	Mean	23.448	23.71	24.08	24.52	24.872	25.30	25.69	27.26	
h	0	31.1	31	30.9	30.6	30.6	30.5	30.3	29.9	30.61
	30	32.4	32.3	32.2	32	31.8	31.6	31.3	30	31.70
	60	34.8	34.7	34.4	34.1	33.9	33.7	33.3	32.6	33.94
	90	35.6	35.4	35.2	35	34.9	34.5	34.1	33.7	34.80
	120	36.7	36.3	36	35.8	35.4	35.2	35	33.4	35.48
	Mean	34.12	33.94	33.74	33.5	33.32	33.1	32.8	31.92	
ΔE	0	0	0.37	0.89	1.38	1.88	2.38	2.88	4.40	1.78
	30	0	0.75	1.48	1.90	2.45	2.93	3.71	5.04	2.29
	60	0	0.73	1.47	1.95	2.48	2.98	3.8	5.18	2.33
	90	0	0.79	1.48	2.08	2.59	3.11	3.92	5.42	2.43
	120	0	0.77	1.48	2.02	2.63	3.18	4.02	5.59	2.46
	Mean	0	0.68	1.36	1.87	2.40	2.92	3.66	5.12	

C.D (p≤0.05)

Treatment (T) = 0.024
Storage (S) = 0.012
TXS = NS

At (0) days of storage the untreated samples had (ΔE) value of 0.00, whereas treated samples had (ΔE) values of 0.375 to 4.406. Maximum (ΔE) value of 4.406 was recorded in samples pretreated with T₇ solution. The (ΔE) values recorded after 120 days of storage varied from 0.773 to 5.592 in treated samples compared to (ΔE) value of 0.00 in control samples. Maximum (ΔE) value was observed in samples pretreated with T₇ solution.

4.4 Experiment No. 3: Effect of packaging materials and storage period on quality attributes of chilli powder

4.4.1 Physico-chemical characteristics of dried chilli powder

4.4.1.1 Moisture content (% db)

Effect of drying methods, packaging materials and storage period on moisture content (% db) of chilli powder samples is indicated in Table 19.

The moisture content of chilli powder prepared from chilli dried under sun, solar tunnel drier and mechanical drier at 45°C was 9.19, 9.14 and 9.10% (db) respectively at (0) days of storage. During storage of 120 days there was significant increase in moisture content in all chilli powder samples due to drying method, packaging material and storage period. In LDPE pouches maximum mean moisture content of 9.29% (db) was recorded in chilli powder prepared from sun dried chillies during 120 days of storage, followed by 9.23% (db) in chilli powder prepared from solar tunnel dried chillies whereas, minimum moisture content 9.21% (db) was observed in chilli powder prepared from mechanical dried chillies.

An increase in moisture content during 120 days of storage was also observed in chilli powder samples when packed in MLP pouches. The maximum mean moisture content of 9.27% db was recorded during 120 days of storage in chilli powder prepared from sun drying, followed by 9.22% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum moisture content of 9.16% (db) in chilli powder samples prepared from mechanical dried chillies.

Table 19: Effect of packaging materials, drying methods and storage period on moisture (% db) of dried chilli powder (Kashmir Long-1)

Packaging Material	Storage [Days]																		Overall Mean
	Sun dried powder						Solar tunnel dried powder						Mechanical dried Powder						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
MLP	9.19	9.23	9.27	9.31	9.36	9.27	9.14	9.2	9.23	9.26	9.29	9.22	9.10	9.13	9.16	9.19	9.22	9.16	9.22
LDPE	9.19	9.24	9.29	9.33	9.38	9.29	9.14	9.19	9.23	9.28	9.33	9.23	9.10	9.15	9.20	9.26	9.32	9.21	9.24
VP	9.19	9.20	9.20	9.22	9.24	9.21	9.14	9.15	9.15	9.17	9.18	9.16	9.10	9.10	9.11	9.13	9.15	9.12	9.16
Mean	9.19	9.22	9.25	9.29	9.33	9.26	9.14	9.18	9.20	9.24	9.27	9.21	9.10	9.13	9.16	9.19	9.23	9.16	9.21
Storage mean	9.14	9.18	9.20	9.24	9.27														

C.D (p≤0.05)

Packaging Material (PM)	=	0.021
Storage (S)	=	0.03
Drying Method (DM)	=	0.022
PM x S	=	NS
PM x DM	=	NS
S x PM	=	0.121
PM x S x DM	=	NS

Among the packages used for storage studies of chilli powder samples, vacuum packaged MLP pouches indicated lowest increase in moisture content throughout 120 days of storage. The mean moisture content of 9.21%(db) was recorded during 120 days of storage in chilli powder prepared from sun dried chillies followed by 9.16% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum moisture content of 9.12% (db) in chilli powder prepared from mechanical dried chillies.

Irrespective of methods of drying of chillies the mean moisture content during 120 days of storage was recorded in chilli powder packed in LDPE pouches was 9.24%(db) followed by 9.22% (db) in chilli powder samples packed in MLP pouches. The minimum moisture content of 9.16%db was recorded in vacuum packaged MLP pouches.

4.4.1.2 Ascorbic acid (mg/100g db)

Effect of drying methods, packaging materials and storage period on ascorbic acid (mg/100g db) of chilli powder samples is indicated in Table 20.

The ascorbic acid content of chilli powder samples prepared from chillies dried under sun, solar tunnel drier and mechanical drier at 45°C was 32.62, 33.04, 47.01 mg/100g (db) respectively at 0 days of storage. During storage of 120 days there was significant decrease in ascorbic acid (mg/100g db) of all chilli powder samples due to method of drying, packaging material and storage. The maximum mean ascorbic acid content of 45.79mg/100g (db) during 120 days of storage was recorded in mechanical dried chilli powder samples packed in LDPE pouches followed by 31.92 mg/100g (db) in solar tunnel dried chilli powder samples whereas, minimum ascorbic acid 31.23 mg/100g (db) was observed in chilli powder prepared from sun drying packed in LDPE pouches.

A decrease in ascorbic acid during 120 days of storage was also observed in chilli powder packed in MLP pouches. The maximum mean ascorbic acid

46.12mg/100g db was recorded during 120 days of storage in chilli powder prepared

Table 20: Effect of packaging materials, drying methods and storage period on ascorbic acid (mg/100 db) of dried chilli powder (Kashmir Long-1)

Packaging Material	Storage [Days]																		Overall Mean
	Sun dried powder						Solar tunnel dried powder						Mechanical dried Powder						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
MLP	32.62	32	31.4	30.78	30.18	31.40	33.04	32.68	32.33	31.96	31.62	32.33	47.01	46.56	46.12	45.68	45.25	46.12	36.62
LDPE	32.62	31.65	31.14	30.61	30.12	31.23	33.04	32.37	31.88	31.39	30.9	31.92	47.01	46.33	45.77	45.2	44.63	45.79	36.31
VP	32.62	32.42	31.86	31.32	32.15	32.07	33.04	32.84	32.43	32	32.64	32.59	47.01	47.34	46.83	46.33	47.09	46.92	37.19
Mean	32.62	32.02	31.47	30.90	30.82	31.57	33.04	32.63	32.21	31.78	31.72	32.28	47.01	46.74	46.24	45.74	45.66	46.28	36.71
Storage mean	37.56	37.13	36.64	36.14	36.06														

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C.D (p≤0.05)

Packaging Material (PM)	=	0.795
Storage (S)	=	0.033
Drying Method (DM)	=	0.048
PM x S	=	1.778
PM x DM	=	NS
S x PM	=	NS
PM x S x DM	=	NS

from mechanical drying, followed by 32.33 mg/100g db in chilli powder samples prepared from solar tunnel dried chillies and minimum ascorbic acid of 31.40mg/100g in sun dried samples.

Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest decrease in ascorbic acid throughout 120 days of storage. The maximum mean ascorbic acid of 46.92 mg/100g (db) was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 32.59 mg/100g (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum ascorbic acid of 32.07 mg/100g db in chilli powder prepared from sun dried chillies.

Irrespective of methods of drying of chillies the minimum mean ascorbic acid during 120 days of storage was recorded in LDPE packed samples as 36.31 mg/100g (db) followed by 36.62 mg/100g (db) in chilli powder samples packed in MLP pouches. The maximum ascorbic acid content of 37.19 mg/100g (db) was recorded in vacuum packaged samples in MLP pouches.

4.4.1.3 Capsaicin (% db)

Effect of drying methods, packaging materials and storage period on capsaicin content (% db) of chillies powder samples is indicated in Table 21.

The capsaicin content of chilli powder prepared from chillies dried under sun, solar tunnel drier and mechanical drier at 45°C was 0.70, 0.74, 0.90% (db) respectively at (0) days of storage. During storage of 120 days there was significant decrease in capsaicin content of all chilli powder samples. In LDPE pouches the maximum mean capsaicin content of 0.82%(db) during 120 days of storage was recorded in mechanically dried samples followed by 0.70%(db) in solar tunnel dried chilli powder samples, whereas, minimum capsaicin content of 0.65%(db) was observed in chilli powder prepared from sun drying.

A decrease in capsaicin content during 120 days of storage was also observed in chilli powder samples when packed in MLP pouches. The maximum

Table 21: Effect of packaging materials, drying methods and storage period on capsaicin (% db) of dried chilli powder (Kashmir Long-1)

Packaging Material	Storage [Days]																		Overall Mean
	Sun dried powder						Solar tunnel dried powder						Mechanical dried Powder						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
MLP	0.70	0.67	0.64	0.62	0.59	0.64	0.74	0.72	0.71	0.69	0.68	0.71	0.90	0.87	0.83	0.8	0.77	0.83	0.73
LDPE	0.70	0.68	0.65	0.62	0.59	0.65	0.74	0.71	0.70	0.68	0.67	0.70	0.90	0.85	0.82	0.78	0.75	0.82	0.72
VP	0.70	0.69	0.66	0.63	0.60	0.66	0.74	0.73	0.72	0.7	0.69	0.72	0.90	0.89	0.86	0.82	0.79	0.85	0.74
Mean	0.70	0.68	0.65	0.62	0.59	0.65	0.74	0.72	0.71	0.69	0.68	0.71	0.90	0.87	0.84	0.80	0.77	0.83	0.73
Storage mean	0.78	0.76	0.73	0.70	0.68														

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C.D (p<0.05)

Packaging Material (PM)	=	0.039
Storage (S)	=	NS
Drying Method (DM)	=	0.02
PM x S	=	0.088
PM x DM	=	NS
S x PM	=	NS
PM x S x DM	=	NS

mean capsaicin content of 0.83% (db) was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 0.71% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum capsaicin content of 0.64% (db) in sun dried samples.

Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest decrease in capsaicin content throughout 120 days of storage. The maximum mean capsaicin content of 0.85% (db) was recorded during 120 days of storage in chilli powder prepared from mechanical drier, followed by 0.72% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum capsaicin content of 0.66% db in sun dried samples.

Irrespective of methods of drying of chillies, the minimum mean capsaicin content during 120 days of storage was recorded in LDPE packed samples as 0.72% (db) followed by 0.73% (db) in chilli powder samples packed in MLP pouches. The maximum capsaicin content of 0.74% (db) was recorded in vacuum packaged samples.

4.4.1.4 Capsanthin (ASTA units)

Effect of drying methods, packaging materials and storage period on capsanthin content (ASTA units) of chilli powder samples is indicated in Table 22.

The capsanthin content of chilli powder prepared from chillies dried under sun, solar tunnel drier and mechanical drier at 45°C was 121.44, 122.58, 132.03 ASTA units respectively at 0 days of storage. During storage of 120 days there was significant decrease in capsanthin content of all chilli powder samples. In LDPE pouches the maximum mean capsanthin content of 130.90 ASTA units during 120 days of storage was recorded in powder prepared from mechanically dried chillies followed by 121.14 ASTA units in solar tunnel dried chilli powder samples, whereas, minimum capsanthin content of 120.05 ASTA units was observed in chilli powder prepared from sun drying.

Table 22: Effect of packaging materials, drying methods and storage period on capsanthin (ASTA) of dried chilli powder (Kashmir Long-1)

Packaging Material	Storage [Days]																		Overall Mean
	Sun dried powder						Solar tunnel dried powder						Mechanical dried Powder						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
LDPE	121.44	120.72	120.04	119.34	118.68	120.05	122.58	121.85	121.14	120.43	119.72	121.14	132.03	131.46	130.89	130.32	129.77	130.9	124.03
MLP	121.44	119.21	118.44	117.7	116.95	118.75	122.58	119.52	118.86	118.23	117.6	119.36	132.03	130.38	129.73	129.06	128.43	129.93	122.68
VP	121.44	122.69	121.84	120.98	120.11	121.41	122.58	125.17	124.37	123.55	122.78	123.69	132.03	133.39	132.76	132.16	131.55	132.38	125.83
Mean	121.44	120.87	120.11	119.34	118.58	120.07	122.58	122.18	121.46	120.74	120.03	121.40	132.03	131.74	131.13	130.51	129.92	131.07	124.18
Storage mean	125.35	124.9322	124.23	123.53	122.8433														

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C.D (p≤0.05)

Packaging Material (PM)	=	1.012
Storage (S)	=	1.034
Drying Method (DM)	=	NS
PM x S	=	NS
PM x DM	=	3.08
S x PM	=	3.06
PM x S x DM	=	NS

A decrease in capsanthin content during 120 days of storage was also observed in chilli powder samples packed in MLP pouches. The maximum mean capsanthin content 129.93 ASTA units was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 119.36 ASTA units in chilli powder samples prepared from solar tunnel dried chillies and minimum capsanthin content of 118.75 ASTA units in powder prepared from sun dried chillies.

Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest decrease in capsanthin content throughout 120 days of storage. The maximum mean capsanthin content 132.38 ASTA units was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 123.69 ASTA units in chilli powder samples prepared from solar tunnel dried chillies and minimum capsanthin content of 121.41 ASTA units in chilli powder prepared from sun dried chillies.

Irrespective of methods of drying of chillies, the minimum mean capsanthin content during 120 days of storage was recorded in LDPE packed samples as 124.03 ASTA units followed by 122.68 ASTA units in chilli powder samples packed in MLP pouches. The maximum capsanthin content of 125.83 ASTA units was recorded in vacuum packaged samples.

4.4.1.5 Non Enzymatic Browning

Effect of drying methods, packaging materials and storage period on non-enzymatic browning values of chilli powder samples is indicated in Table 23.

The non-enzymatic browning values of chilli powder prepared from chilli dried under sun, solar tunnel drier and mechanical drier at 45°C was 0.092, 0.088, 0.060 respectively at 0 days of storage. During storage of 120 days there was significant increase in non-enzymatic browning values of all chilli powder samples. In LDPE pouches the maximum mean non-enzymatic browning value of 0.205 during 120 days of storage was recorded in chilli powder prepared from sun

Table 23: Effect of packaging materials, drying methods and storage period on non-enzymatic browning values(OD at 420 nm) of dried chilli powder (KashmirLong-1)

Packaging Material	Storage [Days]																		Overall Mean
	Sun dried powder						Solar tunnel dried powder						Mechanical dried Powder						
	0	30	60	90	120	Mean	0	30	60	90	120	Mean	0	30	60	90	120	Mean	
MLP	0.092	0.113	0.166	0.219	0.27	0.172	0.088	0.099	0.106	0.113	0.12	0.105	0.06	0.093	0.099	0.104	0.109	0.093	0.123
LDPE	0.092	0.166	0.21	0.256	0.3	0.205	0.088	0.116	0.127	0.137	0.147	0.123	0.06	0.103	0.111	0.118	0.125	0.103	0.144
VP	0.092	0.089	0.116	0.163	0.21	0.134	0.088	0.079	0.093	0.096	0.1	0.091	0.06	0.068	0.084	0.088	0.093	0.079	0.101
Mean	0.092	0.123	0.164	0.213	0.260	0.170	0.088	0.098	0.109	0.115	0.122	0.106	0.060	0.088	0.098	0.103	0.109	0.092	0.123
Storage mean	0.080	0.103	0.124	0.144	0.164														

06

C.D (p<0.05)

Packaging Material (PM)	=	0.006
Storage (S)	=	0.029
Drying Method (DM)	=	0.028
PM x S	=	NS
PM x DM	=	NS
S x PM	=	NS
PM x S x DM	=	NS

amples followed by 0.123 in chilli powder prepared from solar tunnel dried chillies whereas, minimum non-enzymatic browning value of 0.103 was observed in chilli powder prepared from mechanically dried chillies.

An increase in non-enzymatic browning during 120 days of storage was also observed in chilli powder samples obtained from sun, solar tunnel drier and mechanical drier when packed in MLP pouches. The maximum mean non-enzymatic browning value of 0.172 was recorded during 120 days of storage in chilli powder prepared from sun dried chillies, followed by 0.105 in chilli powder samples prepared from solar tunnel dried chillies and minimum non-enzymatic browning value of 0.093 in chilli prepared from mechanical dried chillies.

Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest increase in non-enzymatic browning values throughout 120 days of storage. The mean non-enzymatic browning value of 0.134 was recorded during 120 days of storage in chilli powder prepared from sun drying, followed by 0.091 in chilli powder samples prepared from solar tunnel dried chillies and minimum non-enzymatic browning value of 0.079 in chillies prepared from mechanically dried chillies.

Irrespective of methods of drying of chillies the maximum mean non-enzymatic browning values during 120 days of storage was recorded in LDPE packed samples as 0.144 followed by 0.123 in chilli powder samples packed in MLP pouches. The minimum non-enzymatic browning value of 0.101 was recorded in vacuum packaged pouches.

4.4.1.6 Colour values (L^* , a^* , b^* , c , h (ΔE)) in chilli powder.

Effect of drying methods, packaging materials and storage period on colour values (L^* , a^* , b^* , c , h (ΔE)) of chillies powder samples is indicated in Table 24.

Drying methods influenced non significantly the colour parameter of chilli powder prepared from chillies after pretreatments with T_7 solution. The powder

prepared mechanically had highest L^* , a^* , b^* , c and h values followed by solar tunnel dried samples and sun dried samples. At (0) days of storage maximum L^* , a^* , b^* , c and h values recorded in mechanically dried chilli powder were 32.19, 32.62, 39.01, 50.85 and 50.10 followed by 31.82, 31.71, 38.81, 50.12 and 50.70 in solar tunnel dried samples and minimum 30.17, 30.10, 37.02, 47.71 and 50.90 in sun dried samples.

During storage there was decline in L^* , a^* , b^* , c values and increase in h and ΔE values significantly influenced by packaging material. Vacuum packaging helped to retain maximum L^* , a^* , b^* values followed by MLP and LDPE. The L^* value after 120 days of storage varied from 31.96 to 32.05. During 120 days of storage the maximum mean L^* , a^* , b^* , c , h and ΔE values recorded in mechanically dried, vacuum packaged chilli powder samples were 32.05, 32.26, 38.83, 50.37, 50.34 and 0.59 followed by 30.96, 32.13, 38.72, 50.32, 50.30 and 0.61 in mechanically dried chilli powder packed in MLP pouches. The mean minimum L^* , a^* , b^* , c , h and ΔE values recorded were 31.90, 32.07, 38.06, 49.76, 49.92 and 1.01 chilli powder packed in LDPE pouches. The maximum mean L^* , a^* , b^* , c , h and ΔE values during 120 days of storage recorded in solar tunnel dried vacuum packaged chilli powder samples were 31.23, 31.07, 49.22, 50.84 and 1.28 followed by 31.13, 30.98, 37.96, 48.99, 50.78 and 1.32 in solar tunnel dried chilli powder packed in MLP pouches. The minimum mean L^* , a^* , b^* , c , h and ΔE values recorded were 31.04, 30.86, 37.83, 48.82, 50.78 and 1.17 in chilli powder packed in LDPE pouches.

The maximum mean L^* , a^* , b^* , c , h and ΔE values during 120 days of storage recorded in sun dried vacuum packaged chilli powder samples were 29.76, 29.79, 37.07, 47.55, 51.22 and 0.76 followed by sun dried chilli powder packed in MLP pouches as 29.67, 29.67, 36.89, 47.34, 51.08 and 0.67 and the minimum mean L^* , a^* , b^* , c , h and ΔE values recorded were 29.63, 29.60, 36.48, 46.85, 51.34 and 0.80 chilli powder packed in LDPE pouches.

Table-24: Effect of packaging materials, drying methods and storage period on L*,a*,b* values of dried chilli powder (Kashmir long-1)

Drying Method	Colour value	MLP					Mean	LDPE					Mean	VP					Mean	Overall mean
		0	30	60	90	120		0	30	60	90	120		0	30	60	90	120		
Sun drying	L*	30.17	29.91	29.67	29.42	29.18	29.67	30.17	29.85	29.61	29.38	29.15	29.63	30.17	30.06	29.79	29.53	29.27	29.76	29.69
	a*	30.1	29.88	29.67	29.46	29.25	29.67	30.1	29.76	29.57	29.38	29.2	29.60	30.1	30.06	29.82	29.59	29.36	29.79	29.69
	b*	37.02	36.95	36.89	36.82	36.76	36.89	37.02	36.72	36.47	36.21	35.96	36.48	37.02	37.28	37.15	37.01	36.88	37.07	36.81
	c	47.71	47.52	47.34	47.16	46.98	47.34	47.71	47.27	46.95	46.01	46.32	46.85	47.71	47.89	47.64	47.38	47.15	47.55	47.25
	h	50.9	51	51.2	51.3	51.5	51.18	50.9	51	51	51.9	51.9	51.34	50.9	51.1	51.2	51.4	51.5	51.22	51.25
Solar drying	ΔE	0	0.35	0.67	1.01	1.33	0.67	0	0.41	0.8	1.2	1.58	0.80	0	0.38	0.77	1.14	1.51	0.76	0.74
	L*	31.82	31.47	31.12	30.78	30.44	31.13	31.82	31.33	31.01	30.69	30.37	31.04	31.82	31.6	31.26	30.91	30.57	31.23	31.14
	a*	31.71	31.33	30.97	30.61	30.26	30.98	31.71	31.17	30.82	30.47	30.13	30.86	31.71	31.48	31.1	30.72	30.35	31.07	30.97
	b*	38.81	38.37	37.96	37.53	37.11	37.96	38.81	38.07	37.75	37.41	37.09	37.83	38.81	38.57	38.2	37.83	37.46	38.17	37.99
	c	50.12	49.54	48.99	48.43	47.88	48.99	50.12	49.2	48.73	48.25	47.79	48.82	50.12	49.79	49.26	48.73	48.21	49.22	49.01
Mechanical drying	h	50.7	50.8	50.8	50.8	50.8	50.78	50.7	50.7	50.8	50.8	50.9	50.78	50.7	50.8	50.8	50.9	51	50.84	50.80
	ΔE	0	0.68	1.33	1.98	2.63	1.32	0	0.6	1.17	1.76	2.32	1.17	0	0.65	1.28	1.92	2.54	1.28	1.26
	L*	32.19	32.07	31.96	31.84	31.73	31.96	32.19	31.98	31.88	31.78	31.68	31.90	32.19	32.19	32.07	31.95	31.84	32.05	31.97
	a*	32.62	32.38	32.13	31.89	31.65	32.13	32.62	32.3	32.05	31.8	31.56	32.07	32.62	32.43	32.2	31.99	31.77	32.20	32.13
	b*	39.01	38.87	38.72	38.58	38.44	38.72	39.01	38.45	38.03	37.61	37.18	38.06	39.01	39.02	38.86	38.71	38.56	38.83	38.54
over all storage mean	c	50.85	50.59	50.31	50.05	49.79	50.32	50.85	50.22	49.73	49.25	48.77	49.76	50.85	50.47	50.37	50.22	49.96	50.37	50.15
	h	50.1	50.2	50.3	50.4	50.5	50.3	50.1	50.1	49.7	49.8	49.9	49.92	50.1	50.3	50.4	50.4	50.5	50.34	50.19
	ΔE	0	0.3	0.61	0.92	1.22	0.61	0	0.52	1.01	1.51	2.02	1.01	0	0.3	0.6	0.89	1.17	0.59	0.74
	L*	31.39	31.15	30.92	30.68	30.45	30.92	31.39	31.05	30.83	30.62	30.40	30.86	31.39	31.28	31.04	30.80	30.56	31.01	
	a*	31.48	31.20	30.92	30.65	30.39	30.93	31.48	31.08	30.81	30.55	30.30	30.84	31.48	31.32	31.04	30.77	30.49	31.02	
b*	38.28	38.06	37.86	37.64	37.44	37.86	38.28	37.75	37.42	37.08	36.74	37.45	38.28	38.29	38.07	37.85	37.63	38.02		
c	49.56	49.22	48.88	48.55	48.22	48.88	49.56	48.90	48.47	47.84	47.63	48.48	49.56	49.38	49.09	48.78	48.44	49.05		
h	50.57	50.67	50.77	50.83	50.93	50.75	50.57	50.60	50.50	50.83	50.90	50.68	50.57	50.73	50.80	50.90	51.00	50.80		
ΔE	0	0.44	0.87	1.3	1.72	0.87	0	0.51	1	1.49	1.97	0.99	0	0.44	0.88	1.31	1.74	0.88		

C.D (p≤0.05)

Packaging material (PM)	=	0.367
Storage (S)	=	0.273
Drying Method (DM)	=	N.S
PM x S	=	0.82
PM x DM	=	N.S
S x PM	=	N.S
PM x S x DM	=	0.044

Irrespective of methods of drying and packaging materials used, the colour values L^* , a^* , b^* , c decreased and over all mean values recorded were 31.01, 31.02, 38.02 and 49.05. The h and ΔE values increased and maximum values recorded were 50.80 and 0.88.

4.4.1.7 Moisture sorption isotherm

Table 25 shows the effect of pre-treatment, drying methods and storage periods on moisture sorption isotherm of dried chilli powder which depicted that the chilli powder samples prepared by different methods and packed in LDPE, MLP or vacuum packaged indicated significant gain in moisture content during storage. The significant interaction effect was observed due to storage period and packaging material on changes in water activity and moisture content. The sun dried powder had an initial moisture content of 9.14 percent and a_w of 0.16 which increased during 120 days of storage. The mean values of moisture content and a_w recorded after 120 days of storage were maximum (9.34 percent and 0.534) in chilli powder samples packed in LDPE pouches followed by (9.25 percent and 0.511) in chilli samples packed in MLP pouches and minimum moisture content (9.23 percent and 0.405) recorded in vacuum packaged chilli powder samples.

The solar tunnel dried chilli powder samples had an initial moisture content of 9.19 per cent and a_w 0.14 which increased during 120 days of storage. The maximum moisture content and a_w values recorded were 9.36 percent and 0.513 in samples packed in LDPE pouches followed by 9.23 percent and 0.491 packed in MLP pouches and minimum moisture content of 9.21 percent and 0.389 in vacuum packaged samples.

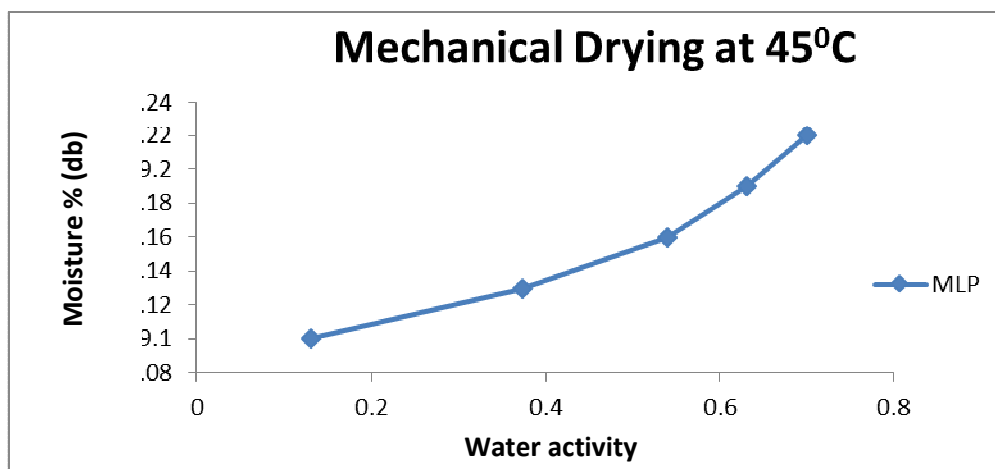
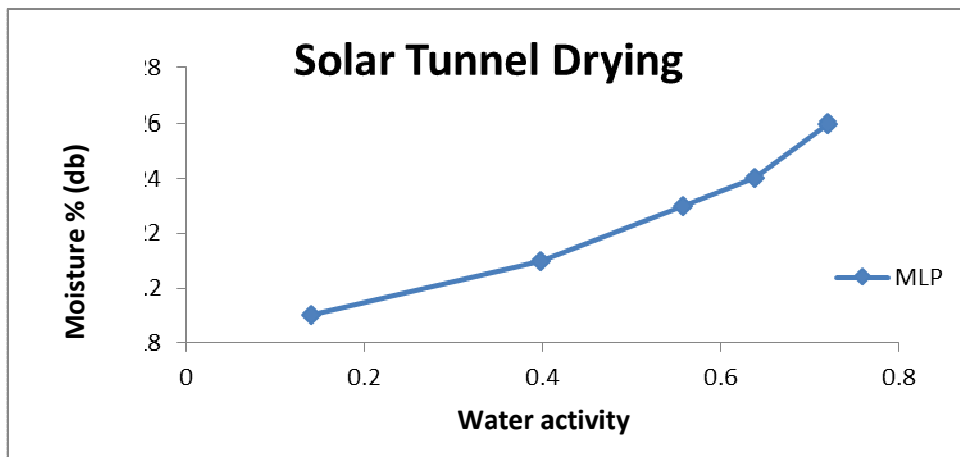
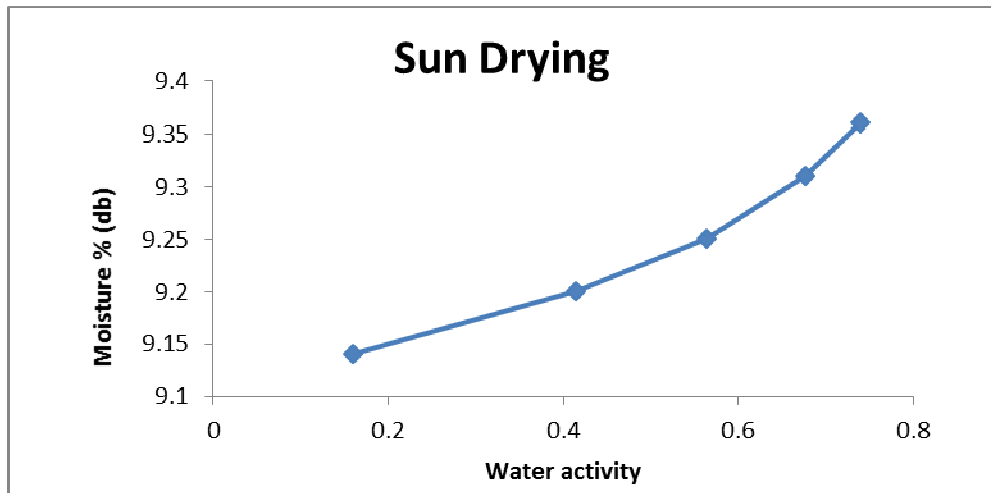
The mechanical dried powder samples had an initial moisture content of 9.10 per cent and a_w 0.13 which increased during 120 days of storage. The maximum moisture content and a_w values recorded were 9.33 percent and 0.498 in samples packed in LDPE pouches followed by 9.16 percent and 0.475 packed in

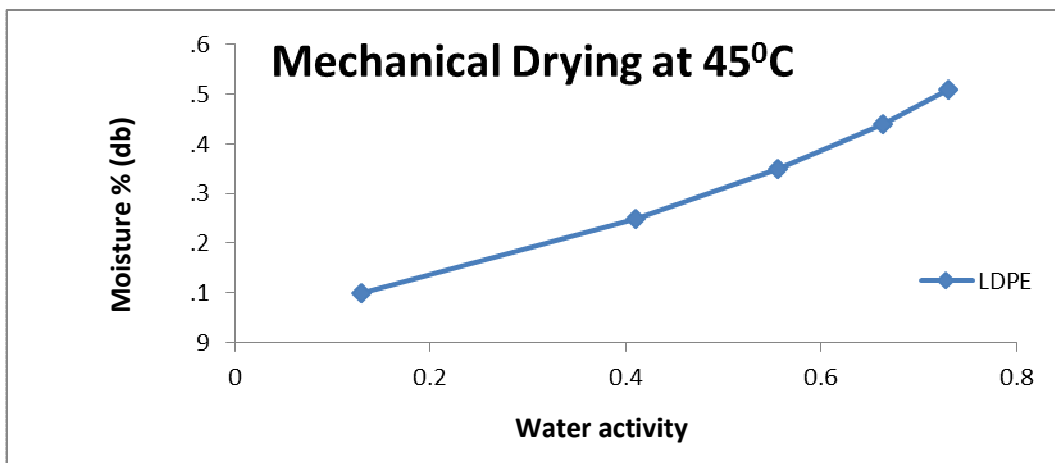
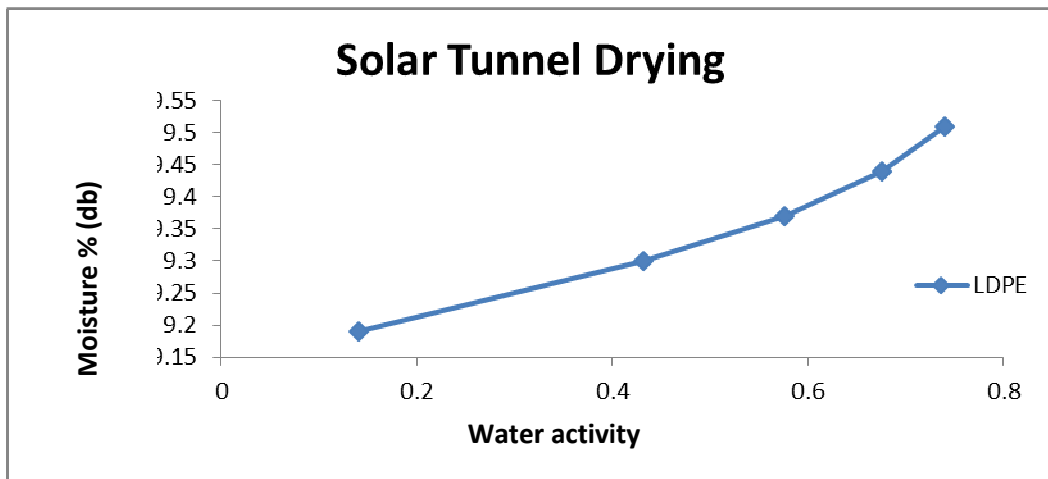
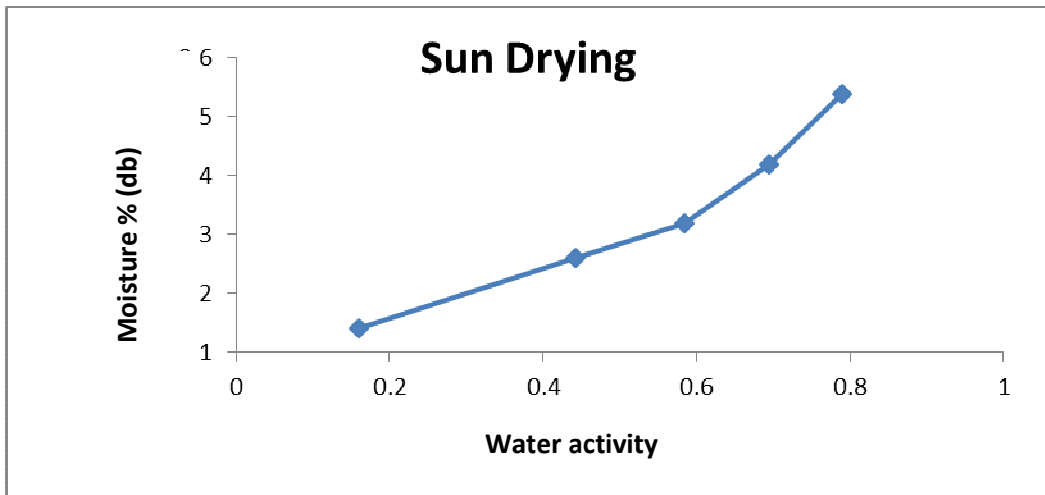
Table-25 : Moisture sorption isotherm of chilli powder (Kashmir Long-1)

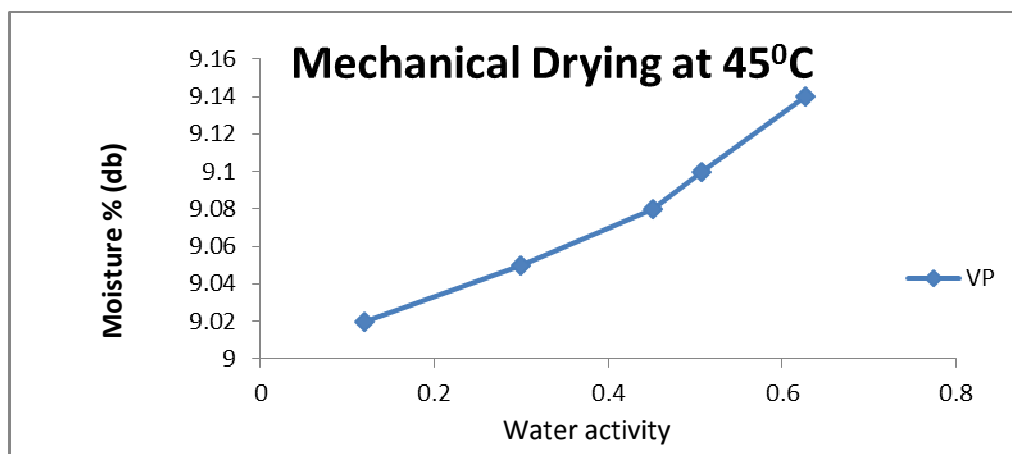
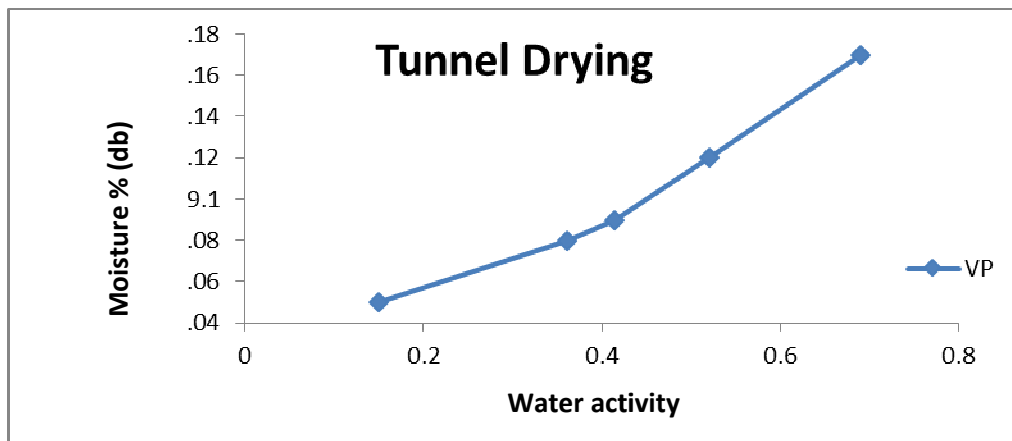
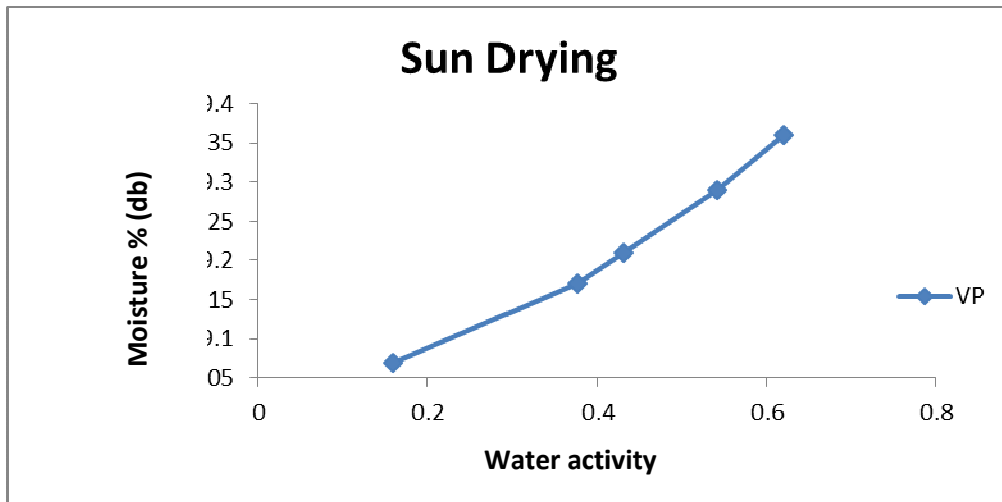
Best Method	0 day		30 days		60 days		90 days		120 days		Mean	
	aW%	Moisture%	aW%	Moisture%	aW%	Moisture%	aW%	Moisture%	aW%	Moisture%	aW%	Moisture%
Metalized Laminated Polyester												
T ₇ SD	0.16	9.14	0.415	9.2	0.564	9.25	0.676	9.31	0.74	9.36	0.511	9.25
T ₇ TD	0.14	9.19	0.398	9.21	0.558	9.23	0.638	9.24	0.72	9.26	0.491	9.23
T ₇ MD	0.13	9.1	0.373	9.13	0.54	9.16	0.631	9.19	0.7	9.22	0.475	9.16
Low Density Polyethene												
T ₇ SD	0.16	9.14	0.443	9.26	0.584	9.32	0.695	9.42	0.79	9.54	0.534	9.34
T ₇ TD	0.14	9.19	0.432	9.3	0.576	9.37	0.676	9.44	0.74	9.51	0.513	9.36
T ₇ MD	0.13	9.1	0.411	9.25	0.556	9.35	0.663	9.44	0.73	9.51	0.498	9.33
Vaccum Packaging												
T ₇ SD	0.16	9.14	0.276	9.17	0.43	9.21	0.541	9.29	0.62	9.36	0.405	9.23
T ₇ TD	0.14	9.19	0.261	9.2	0.414	9.21	0.528	9.23	0.6	9.24	0.389	9.21
T ₇ MD	0.13	9.1	0.205	9.11	0.412	9.13	0.503	9.15	0.626	9.17	0.375	9.13
Storage	0.16	9.14	0.38	9.21	0.53	9.26	0.64	9.34	0.72	9.42		
mean	0.14	9.19	0.36	9.24	0.52	9.27	0.61	9.30	0.69	9.34		
	0.13	9.10	0.33	9.16	0.50	9.21	0.60	9.26	0.69	9.30		

CD (p≤0.05)

Packaging material (PM)	=	0.082
Storage (S)	=	0.0199
PMx S	=	0.272







MLP pouches and minimum moisture content of 9.13 percent and 0.375 in vacuum packaged samples.

4.5. Drying studies

4.5.1 Sun and solar tunnel drying

Table 26 shows the effect of pre treatments and methods of drying on final moisture content (db) of chilli samples

Sun drying of experimental chilli samples was carried out during the month of september 2012 & 2013. The maximum temperature recorded during the drying session 22 ± 2 °C and minimum was 12 ± 2 °C, where as maximum RH was $75\pm 2\%$ and minimum was $28\pm 2\%$ recorded over the drying period.

Pre treatments had exercised profound influence on final moisture content of chilli samples. At the end of 84 hour of sun drying un treated samples had maximum moisture content of 14.45% db compared to lower moisture content of 10.94 to 13.65% db in treated samples. Samples pre treated with T₇ solution had 10.43% db moisture at the end of 83 hour followed by 10.94% and 11.43% db recorded after 84 hour in samples pre treated with T₆ and T₅ solution respectively.

There was 28.58% reduction in drying time of chilli samples dried in solar tunnel dryer which had maximum and minimum temperatures of 38 ± 2 and 29 ± 2 °C. The maximum and minimum relative humidity recorded in solar tunnel dryer were 55 ± 2 and $15\pm 2\%$ respectively during the drying studies. Un-treated samples in solar tunnel dryer possessed moisture content of 13.43% db after 60 hours of drying compared to 10.19 to 12.75% db moisture content recorded in pre treated chillies with T₆ to T₁ solution. Minimum moisture content of 9.85% db after 8 hours was recorded in samples pre treated with T₇ solution.

4.5.2 Mechanical drying

Table 27 shows the effect of pre treatments and mechanical drying temperatures on final moisture content (db) of chilli samples.

Table 26: Effect of pre treatments and methods of drying on final moisture content (db) of chilli samples

Pre-treatments	Sun dried		Solar tunnel dried	
	Moisture (% db)	Drying time (h)	Moisture (% db)	Drying time (h)
T ₀	14.45	84	13.43	60
T ₁	43.65	84	12.75	60
T ₂	13.05	84	12.02	60
T ₃	12.72	84	11.64	60
T ₄	12.04	84	11.43	60
T ₅	11.43	84	10.59	60
T ₆	10.94	84	10.19	60
T ₇	10.43	72	9.85	48

Table 27: Effect of pre treatments and mechanical drying temperatures on final moisture content (db) of chilli samples

Pre-treatments	45 °C		55 °C		65 °C	
	Moisture (% db)	Drying Time (h)	Moisture (% db)	Drying Time (h)	Moisture (% db)	Drying Time (h)
T ₀	11.10	36	10.22	19	9.87	10
T ₁	10.94	34	10.06	18	9.70	9
T ₂	10.79	33	9.99	18	9.54	8
T ₃	10.69	32	9.78	18	9.41	8
T ₄	10.60	30	9.59	17	9.24	8
T ₅	10.41	29	9.42	17	9.06	8
T ₆	10.27	28	9.27	16.16	8.90	7.66
T ₇	10.15	26.33	9.09	16	8.72	7

In case of mechanical drying of chilli samples in cabinet dryer, drying temperature played an important role in decreasing the moisture from the sample. At 45 °C un treated samples took 36 hours to reach to final moisture content of 11.10% db where as trtaeted samples took 26.33 to 34 hours to dry to 10.15 to 10.94%db. Chillies pre treated with T₇ solution took 26.33 hours at 45 °C to attain a moisture content of 10.15% db followed by samples pre treated with T₆ solution which attained a moisture content of 10.27% db after 28 hours of drying at 45 °C.

Un treated chilli samples dried at 55 °C took 19 hours to attain a moisture content of 10.22%db , where as, pre treated samples took 16 to 18 hours to attain a moisture content of 9.09 to 10.06% db. Minimum time of 16 hours was required to dry pre treated chillies at 55 °C for attaining minimum moisture content of 9.09% db followed by chilli samples pre treated with T₆ solution which took 16.16 hours to attain final moisture content of 9.27% db. At 65 °C un treated chilli samples took 10 hours to attain moisture content of 9.87% db where as it took 7 to 9 hours for pre treated samplesto attain moisture content of 8.72 to 9.70% db. Chilli samples pre treated with T₇ solution took 7 hours to dry to a moisture content of 8.72% db followed by 8.90% db recorded in T₆ treated samples after 7.66 hours.

4.6 Drying Kinetics

4.6.1 Mathematical Modelling

Table-28 records the R² and RMSE values for drying kinetics. However Fig. 10 and 11 shows the variation in drying behaviour of chillies at three different temperatures and sun and solar drying. The graphs were obtained by plotting weight changes, moisture ratio (Fig. 12) and drying rates v/s time to get the drying curves. Results from Fig. 12 shows that half of the moisture present was removed during first hour of drying. All the chilli samples had moisturecontent in the range of 80-85 per cent on wet basis. Results showed that as the drying proceeds a gradual decrease in water content occurs due to evaporation of water

molecules from the sample. Initially more than about 30 per cent of moisture content was evaporated from all samples in first 30 minutes and more than about 70 per cent in the first 2 hours of drying. Effect of increasing temperature on drying of samples is quite evident from the data as it clearly shows increasing temperature decreases the time duration of drying. Numerous models have been proposed for drying kinetics of various foods. These models clearly reveal the dependence of drying kinetics i.e. drying process on time and temperature. Three models namely Page Model, Newton Model, Hunsdon-Pabis Model were used to evaluate our data. The observed data was fitted in the given models equations. The drying constants were estimated using these model equations. The drying constants were estimated using these model equations. Drying constants ranged widely in 3 models. The empirical drying constants for chillies and coefficient of determination (R^2) at each temperature are given in Table 26. The selection of the best model to describe the drying behaviour of chillies is based on the highest coefficient of determination (R^2) and lowest Chi-square (χ^2) and Root Mean Square Error (RMSE). The Page model showed the highest R^2 values ranging from 0.989 to 0.993. Highest R^2 values of Page model imply that this equation fits the data best. The Chi-square (χ^2) and RMSE in Page model showed a range of 0.00024 to 0.00149 and 0.0127-0.0372. The observations clearly show that Page model fits the data best. In other words Page model describes best the drying characteristics of chillies.

4.6.2 Drying Characteristics of sun, solar tunnel and mechanical drying at (45, 55 and 65°C)

The characteristics of dried chillies (Kashmir Long-1) showed in Table 28(a,b,c,d,e) which depicted that best pretreated chilli samples dried under sun, solar and mechanically dried, the sun dried sample had initial weight of the chilli sample was 500 gm which was reduced to 118.34 gm after 84 hours of drying. The average moisture content decreased from 441.46 to 15.27% db. At the beginning the drying rate and MR was 0 and 1, the drying rate varied from 1.685 to 5.014 and MR decreased from 1 to 0.0676. However the completion of solar

tunnel drying took 48 hours which showed a decrease in weight from 500 to 133.33 gm. The initial average moisture content recorded was 436.86% db which was reduced to 39.72% db after 48 hours of drying. The drying rate varied from 0 to 1.8395 and MR decreased from 1 to 0.1042. The time taken by the chilli samples to dry at mechanical drying of chillies carried out at 45, 55 and 65°C was 1680 minutes (28 hours), 900 minutes (15 hours) and 420 minutes (7 hours) respectively. The decrease in weight of chillies dried at 45°C was from 1500 to 402 gm. However in chillies dried at 55 and 65°C the decrease in weight ranged from 500 to 141.67 gm and 350 to 128.34 gm respectively. The average moisture content decrease from 441.45 to 23.91% db; 424.91 to 53.52% db and 410.85 to 77.29% db respectively in chilli dried at temperatures of 45, 55 and 65°C. The drying rate varied from 0 to 0.00088 and MR decreased from 1 to 0.10589 at 45°C. In 55 and 65°C the drying rate varied from 0 to 0.01616 and 0 to 0.0611 and MR decreased from 1 to 0.1246 at 55°C and 1 to 0.2264 at 65°C.

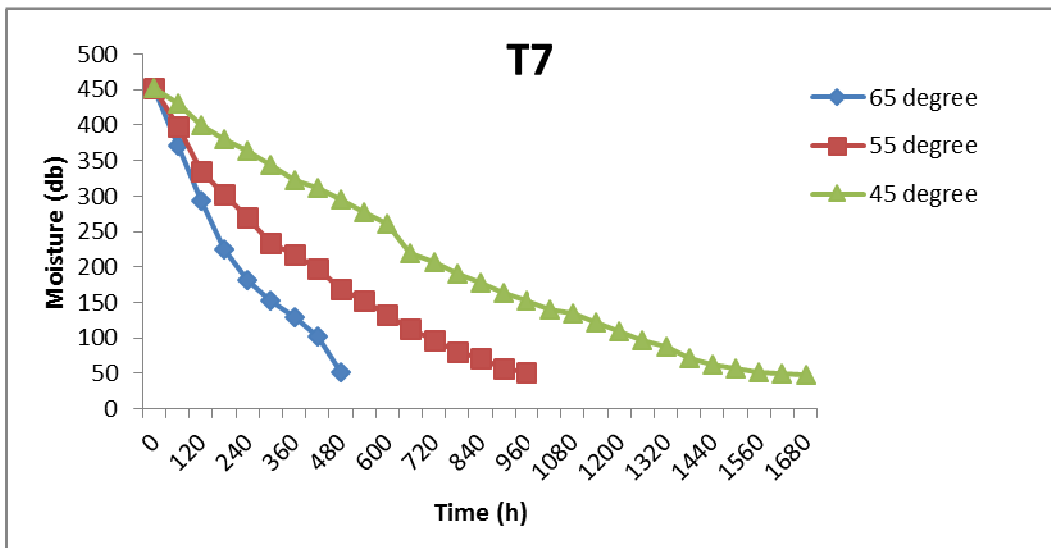
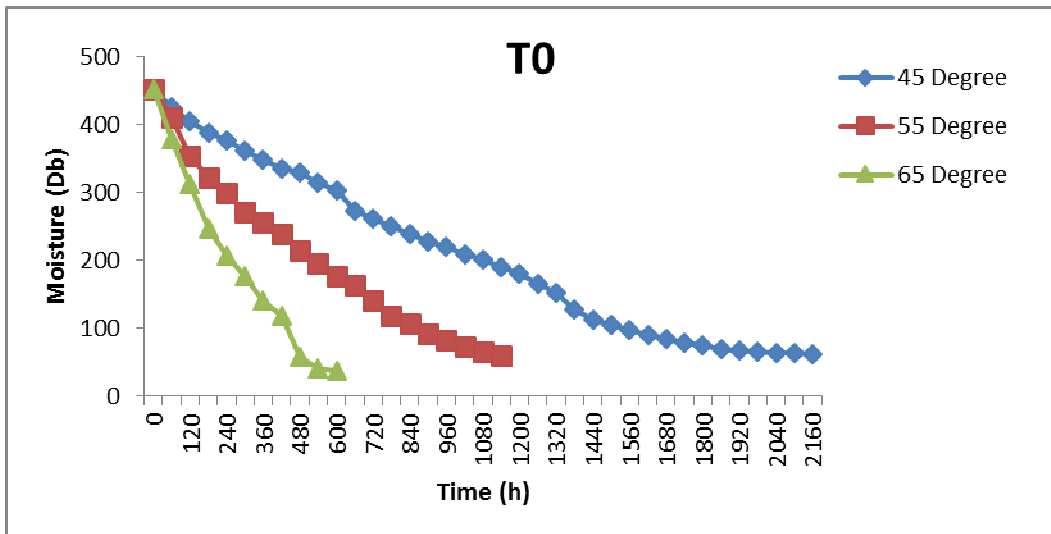


Fig.10: Drying curve depicting changes in moisture and weight v/s time drying mechanical drying

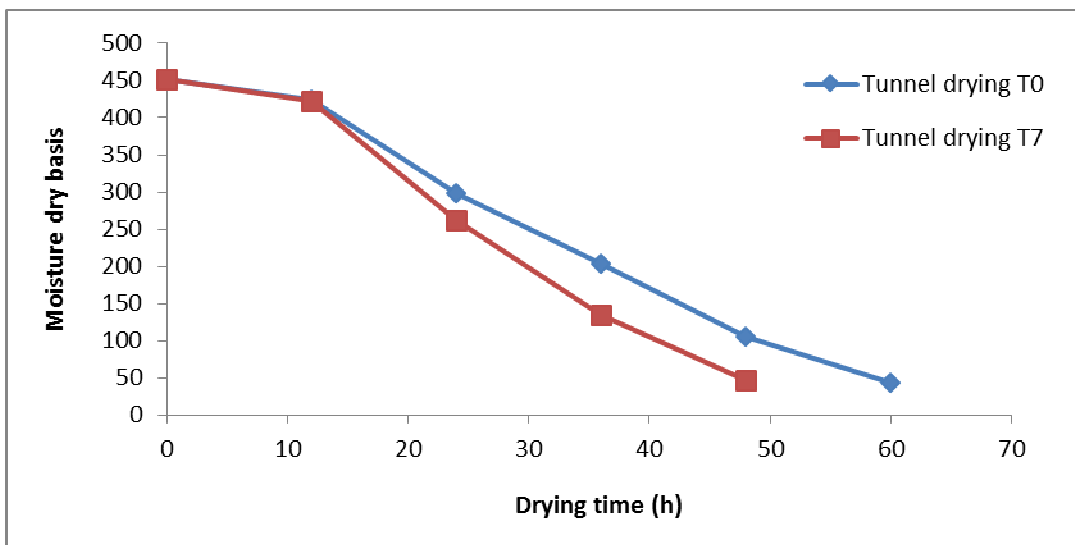
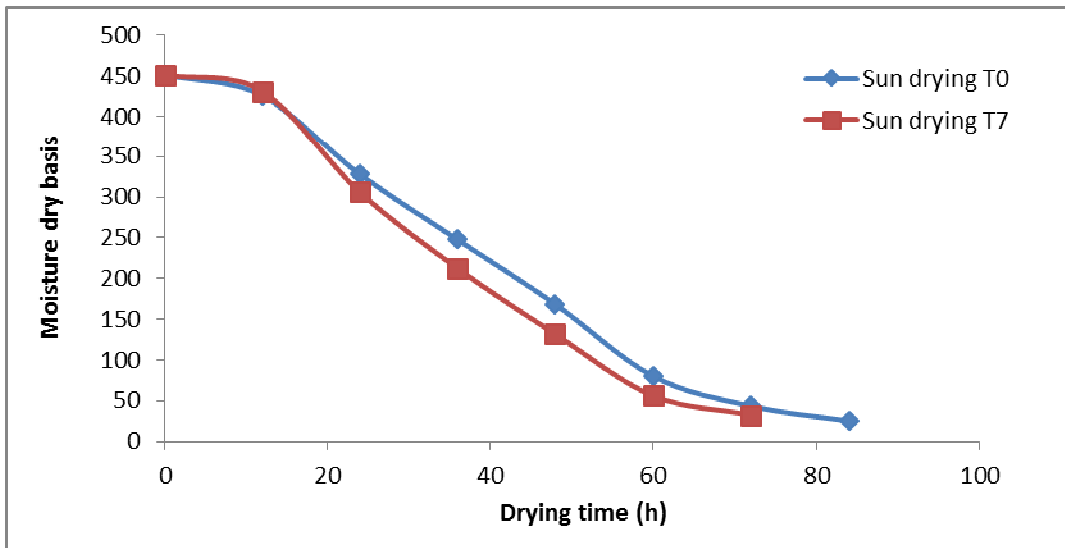


Fig.11: Drying curve depicting change sin moisture v/s time during sun and solar drying

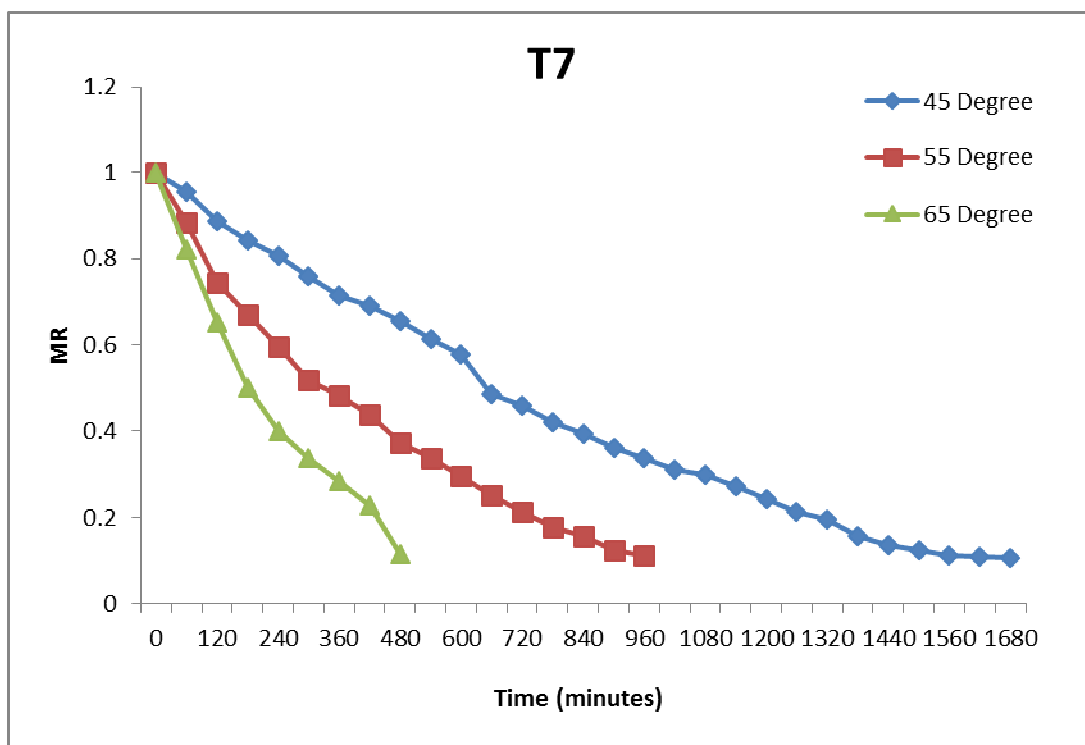
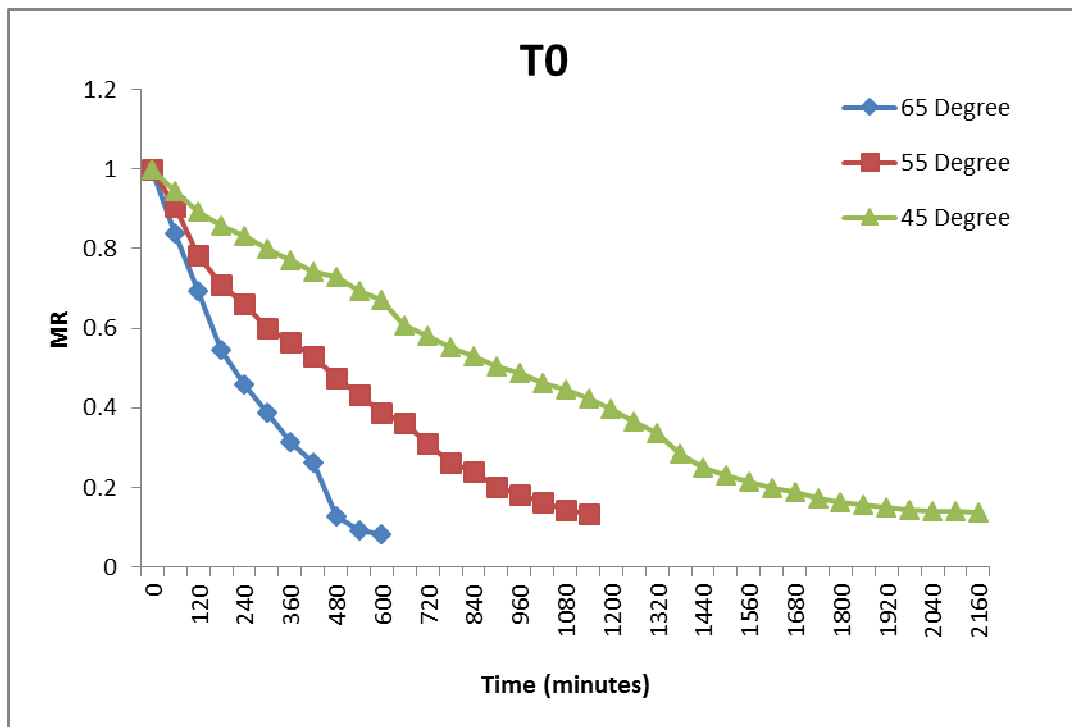


Fig. 12 :Drying curve depicting changes in moisture ratio v/s time

Table 28: Results of Mathematical Modeling

Model	Temperature	K	R²	Chi-square	RMSE	n
Newton	45 °C	K= 0.00061	0.980611	0.001912	0.042963	
	55 °C	K= 0.00096	0.991511	0.000739	0.026366	
	65 °C	K=0.00175	0.965275	0.002984	0.051498	
Page	45 °C	K=0.000159	0.992228	0.001492	0.037227	n=1.167956
	55 °C	K=0.00099	0.993239	0.000244	0.012717	n=0.98711
	65 °C	K=0.001095	0.989608	0.001310	0.031351	n=1.070688
Henderson Pabis	45 °C	K=0.0014	0.980611	0.010136	0.098926	
	55 °C	K=0.00221	0.990532	0.003916	0.060709	
	65 °C	K=0.00404	0.962274	0.018078	0.118578	

Table 28a: Characteristics of sun dried chillies (Kashmir Long -1)

Time (h)	Weight Reduction (gm)	Moisture removed(g)	Moisture present	Solids	Moisture on dry basis	Average moisture (%db)	Drying rate	MR
0	500.00	0.00	409.35	90.65	451.572	0.00	0.000	1
12	481.67	18.33	391.02	90.65	431.351	441.46	1.6859	0.955
24	368.34	131.66	277.69	90.65	306.332	368.84	6.0550	0.678
36	283.34	216.66	192.69	90.65	212.564	259.44	6.6427	0.470
48	210.01	289.99	119.36	90.65	131.671	172.11	6.6682	0.291
60	141.68	358.32	51.03	90.65	56.293	93.98	6.5916	0.124
72	120.01	379.99	29.36	90.65	32.388	44.34	5.8252	0.071
84	118.34	381.66	27.69	90.65	30.546	31.46	5.014	0.067

Table 28b: Characteristics of solar tunnel dried chillies (Kashmir Long -1)

Time (h)	Weight reduction (g)	Moisture removed(g)	Moisture present	Solids	Moisture on dry basis	Average moisture (%db)	Drying rate	MR
0	500.00	0.00	409.35	90.65	451.572	0.000	0.000	1
12	473.33	26.67	382.68	90.65	422.1511	436.861	2.4530	0.9348
24	328.33	171.67	237.68	90.65	262.1953	342.173	6.6685	0.5806
36	213.33	286.67	122.68	90.65	135.3337	198.764	3.5258	0.2996
48	133.33	366.67	42.68	90.65	47.08218	91.207	1.8395	0.1042

Table 28c: Characteristics of mechanical dried chillies at 45°C (Kashmir Long -1)

Time (min)	Weight Reduction (gm)	Moisture removed(g)	Moisture present	Solids	Moisture on dry basis	Average moisture (%db)	Drying rate	MR
0	1500	0	1228.05	271.95	451.572	0.00	0.000	1
60	1445	55	1173.05	271.95	431.3477	441.45	0.339	0.95521
120	1360	140	1088.05	271.95	400.0919	415.71	0.262	0.88599
180	1305	195	1033.05	271.95	379.8676	389.97	0.113	0.84121
240	1260	240	988.05	271.95	363.3205	371.594	0.069	0.80456
300	1205	295	933.05	271.95	343.0962	353.20	0.067	0.75978
360	1150	350	878.05	271.95	322.8719	332.98	0.056	0.71499
420	1120	380	848.05	271.95	311.8404	317.35	0.026	0.69056
480	1075	425	803.05	271.95	295.2933	303.56	0.034	0.65392
540	1025	475	753.05	271.95	276.9075	286.10	0.034	0.61320
600	980	520	708.05	271.95	260.3604	268.63	0.027	0.57656
660	870	630	598.05	271.95	219.9117	240.13	0.061	0.48699
720	835	665	563.05	271.95	207.0417	213.47	0.018	0.45849
780	790	710	518.05	271.95	190.4946	198.76	0.021	0.42184
840	755	745	483.05	271.95	177.6246	184.05	0.015	0.39334
900	715	785	443.05	271.95	162.916	170.27	0.016	0.36077
960	685	815	413.05	271.95	151.8845	157.40	0.011	0.33634
1020	655	845	383.05	271.95	140.8531	146.36	0.010	0.31191
1080	640	860	368.05	271.95	135.3374	138.09	0.005	0.29970
1140	605	895	333.05	271.95	122.4674	128.90	0.011	0.27120
1200	570	930	298.05	271.95	109.5974	116.03	0.010	0.24270
1260	535	965	263.05	271.95	96.72734	103.16	0.010	0.21420
1320	510	990	238.05	271.95	87.53447	92.13	0.007	0.19384
1380	465	1035	193.05	271.95	70.98731	79.26	0.012	0.15720
1440	440	1060	168.05	271.95	61.79445	66.39	0.006	0.13684
1500	425	1075	153.05	271.95	56.27873	59.03	0.003	0.12462
1560	410	1090	138.05	271.95	50.76301	53.52	0.003	0.11241
1620	406	1094	134.05	271.95	49.29215	50.02	0.0009	0.10915
1680	402	1098	130.05	271.95	47.82129	48.55	0.0008	0.10589

Table 28 d: Characteristics of mechanical dried chillies at 55°C (Kashmir Long -1)

Time (min)	Weight reduction (g)	Moisture removed(g)	Moisture present	Solids	Moisture on dry basis	Average moisture (%db)	Drying rate	MR
0	500.00	0.00	409.35	90.65	451.572	0.00	0.00	1
60	451.67	48.33	361.02	90.65	398.257	424.914	0.8890	0.8819
120	395.00	105.00	304.35	90.65	335.741	366.999	0.5212	0.7434
180	365.00	135.00	274.35	90.65	302.647	319.194	0.1839	0.6702
240	335.00	165.00	244.35	90.65	269.553	286.100	0.1379	0.5969
310	303.33	196.67	212.68	90.65	234.616	252.084	0.1127	0.5195
370	288.33	211.67	197.68	90.65	218.069	226.343	0.0447	0.4829
430	270.00	230.00	179.35	90.65	197.848	207.959	0.0470	0.4381
490	243.33	256.67	152.68	90.65	168.428	183.138	0.0600	0.3729
550	228.33	271.67	137.68	90.65	151.880	160.154	0.0301	0.3363
610	211.66	288.34	121.01	90.65	133.491	142.686	0.0301	0.2956
670	193.33	306.67	102.68	90.65	113.270	123.381	0.0301	0.2508
730	178.33	321.67	87.68	90.65	96.7236	104.997	0.0226	0.2141
790	163.33	336.67	72.68	90.65	80.1765	88.4500	0.0209	0.17755
850	155.00	345.00	64.35	90.65	70.98731	75.5819	0.0108	0.1572
910	141.67	358.33	51.02	90.65	56.2824	63.6348	0.0161	0.124637
970	136.67	363.33	46.02	90.65	50.76669	53.5245	0.0056	0.112422

Table 28e: Characteristics of mechanical dried chillies at 65°C (Kashmir Long -1)

Time (min)	Weight reduction (g)	Moisture removed(g)	Moisture present	Solids	Moisture on dry basis	Average moisture (%db)	Drying rate	MR
0	350.00	0.00	286.545	63.455	451.572	0.00	0.00	1
60	298.33	51.67	234.875	63.455	370.1442	410.8581	1.358307	0.8196
120	250	100	186.545	63.455	293.98	332.0621	0.635252	0.6510
180	206.67	143.33	143.215	63.455	225.6954	259.8377	0.379688	0.4997
240	178.34	171.66	114.885	63.455	181.0496	203.3725	0.186186	0.4009
300	160.01	189.99	96.555	63.455	152.163	166.6063	0.093263	0.3369
360	145.01	204.99	81.555	63.455	128.5242	140.3436	0.063944	0.2846
420	128.34	221.66	64.885	63.455	102.2536	115.3889	0.061147	0.2264
480	96.67	253.33	33.215	63.455	52.34418	77.29887	0.101944	0.1159

Chapter – 5

DISCUSSION

The present investigation “Effect of drying methods and packaging materials on storage stability and quality of chillies” was carried out in the processing laboratory of Division of Post Harvest Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar during the year 2011-2012 and 2012-2013.

An attempt has been made in the present investigation to select a best pre-treatment and drying method for getting an acceptable dried chilli which remains stable during storage. The quality with respect to physico-chemical properties of dried chilli was monitored by drawing periodic samples during ambient storage period. The best treatment combination was carried over in preparing chilli powder which was packed in three different packaging materials namely metalized laminated pouches, low density polyethylene, vacuum packaging and evaluated for chemical parameters and moisture sorption isotherms. The results are discussed in this chapter under following headings.

5.1 Physico-chemical characteristics of fresh chilli

Physical parameters recorded revealed that red chilli had an average length of 11.21 cm, average breadth of 1.57 cm, average fruit weight of 9.060 g and seed content 34 per cent. Chemical composition of chilli revealed that it contained 80.686 per cent moisture (wb) and 0.648 per cent db reducing sugar. It had an ascorbic acid of 49.4 mg/100g db, 0.38 per cent capciasin (db) and 98.378 ASTA units capsanthin. The colour values revealed that it had L^* , a^* , b^* values of 32.666, 20.913, 35.805 respectively.

5.2 Experiment No. 1: Effect of pre-treatments, drying methods and storage period on quality of whole chillies (Kashmir Long-1)

5.2.1.1 Moisture content (%)

During drying operation there was reduction in moisture content of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments and methods of drying. At the completion of drying process, the moisture content of open sun dried samples at (0) days of storage was significantly higher than solar tunnel dried samples in all treatments. The moisture content recorded in open sun dried samples without any pre-treatment was maximum 14.45% db where as the moisture content of pre-treated samples varied from 10.43 to 13.65% db. Minimum moisture content (10.43% db) was recorded in samples dried by using T₇ as pre-treatment solution followed by 10.94%db in samples pretreated with T₆ solution. The moisture content of chilli samples at the completion of solar tunnel drying was maximum (13.43% db) in control samples and a lower value of 9.85 to 12.75%db was recorded in pre-treated samples. The pretreatments promotes the quality of the dried chilli as it removes the wax layer of the surface of chillies and allows the water in chilli to diffuse from the surface hence, the drying rate of the peppers is increased (Jyothi *et al.*,2008; Wiriya *et al.*,2009; Kyung *et al.*,2012).

The mean moisture content of sun dried samples at 30, 60, 90 and 120 days of storage was 12.83, 13.19, 13.32, 13.45 compared to the lower values of 12.18, 12.61, 12.79, 12.96%db respectively in solar tunnel dried samples, irrespective of treatments. Irrespective of drying methods and storage periods the untreated samples possessed over all mean moisture content (14.77% db) compared to lower values (10.82 to 13.89% db) in treated samples. Minimum moisture content 10.82 and 11.57% db was recorded in samples pre-treated with T₇ and T₆ solution respectively. The moisture of the dried chilli increased during storage because of its hygroscopic nature. It absorbs moisture from air. Same

results have been depicted by Famurewa *et al.* (2006), Toontom *et al.* (2012), Ajaykumaret *al.* (2012).

5.2.1.2 Ascorbic acid (mg/100g db)

Pre-treatments, methods of drying and storage periods influenced significantly ($p \leq 0.05$) the ascorbic acid content in chilli samples. At the completion of drying process, the ascorbic acid of solar tunnel dried samples at 0 days of storage was significantly ($p \leq 0.05$) higher than sun dried samples in all treatments. The ascorbic acid content of pre treated sundried samples varied from 38.70 to 39.98 mg/100g db at (0) days of storage and control samples recorded the ascorbic acid content of 38.52 mg/100 g db. Maximum ascorbic acid content of 39.98 mg/100g was recorded in sun dried samples pretreated with T₇ solution. The ascorbic acid content of pretreated solar tunnel dried samples at (0) days of storage ranged from 39.62 to 41.08 mg/100g db and control samples recorded 39.47 mg/100g db ascorbic acid. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum ascorbic acid of 41.08 mg/100g db followed by T₆ pre treated samples (40.93 mg/100g db).

Markus *et al.* (1999) reported that loss of ascorbic acid was due to the formation of caramelised products in red pepper by high drying temperature and long time of drying. Ascorbic acid was degraded by higher temperatures and the degradation product L-dehydroascorbic acid, DHHA) participate in the degradation with amino acid, producing a browning pigment. Not only does the higher temperature of drying air affect the loss of ascorbic acid but a long period of drying time can also influence the loss.

The mean ascorbic acid content of sun dried samples at 30, 60, 90 and 120 days of storage was 38.97, 38.70, 38.03, 37.76 mg/100g db compared to the higher values of 40.02, 39.77, 39.10, 38.84mg/100g (db) respectively in solar tunnel dried samples, irrespective of treatments. Irrespective of pretreatments and storage days higher mean ascorbic acid values at all sampling dates were observed

in solar tunnel dried samples (39.59 mg/100g db) compared to (38.53 mg/100g db) in open sun dried samples. Similar decline in the ascorbic acid was recorded by Ajaykumar *et al.* (2012), Ananthi *et al.* (2004), Aniel and Sape (2009), Jyothi *et al.* (2008) and Wiriya *et al.* (2009).

5.2.1.3 Capsaicin (%db)

Since spices are considered non-perishable goods, high stability of quality parameters is a prerequisite. Besides colour, pungency is the major quality attribute of chillies and the spice products obtained from the fruits. While the carotenoid profile and its changes have been a matter of comprehensive studies, reports on the storage stability of capsaicinoids are scarce (Topuz and Ozdemir, 2004; Orak and Demicri, 2005). Pre-treatments and methods of drying influenced significantly ($p \leq 0.05$) the capsaicin content in chilli samples. At the completion of drying process, the capsaicin content of solar tunnel dried samples at (0) days of storage was significantly higher than sun dried samples in all treatments. The capsaicin content of pre treated samples varied from 0.893 to 0.939% db in sun dried samples at (0) days of storage. However control samples recorded the capsaicin content of 0.893% db. The capsaicin content recorded in open sun dried samples using pre-treatment T₇ was maximum 0.939% db followed by (0.925% db) in samples pretreated with T₆ solution. The capsaicin content of pretreated samples dried under solar tunnel drier ranged from 0.993 to 1.077% db and control samples recorded 0.975% db capsaicin. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum capsaicin content of 1.077% followed by T₆ (1.053% db).

The mean capsaicin content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 0.973, 0.922, 0.897, 0.874 compared to the lower values of 0.868, 0.845, 0.816, 0.761% in open sun dried samples, irrespective of treatments. Higher mean capsaicin content values at all sampling dates were observed in solar tunnel dried samples (0.938%) compared to (0.840%) in open sun dried samples irrespective of pretreatments and storage days.

Similar results were observed by and Chatarjee *et al.* (1999), May *et al.* (1999), Anonymous (2005), Schweiggert *et al.* (2005), Jyothi *et al.* (2008) and Sanatombi and Sharma (2008).

5.2.1.4 Capsanthin (ASTA Units)

The main pigment in chilli is capsanthin which is reargarded as functional material because it can stimulate singlet oxygen quenching ability and prevent colour degradation (Aleksandra and Biserka, 2004). The capsanthin content of chilli samples decreased during storage and significantly in all samples. The initial capsanthin content of fresh chillies was 98.378 ASTA units fresh weight basis. Pre-treatments, drying methods and storage period influenced significantly ($p \leq 0.05$) the capsanthin content in chilli samples. At the completion of drying process, the capsanthin content of solar tunnel dried samples at 0 days of storage was significantly higher than open sun dried samples in all treatments. The capsanthin content of pre treated sun dried samples varied from 114.06 to 119.45 ASTA Units at (0) days of storage, however control samples recorded the capsanthin content of 113.64 ASTA Units. The capsanthin content recorded in open sun dried samples using pretreatment T₇ was maximum 119.45 ASTA units. The capsanthin content of pretreated samples dried under solar tunnel drier ranged from 115.74 to 121.51 ASTA Units and control samples recorded 115.19 ASTA Units at (0) days of storage. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum capanthin content of 121.51 ASTA Units followed by T₆ (121.30 ASTA Units).

Higher mean capsanthin content values during 120 days of storage were observed in solar tunnel dried samples (117.38 ASTA units) compared to (115.75 ASTA units) in open sun dried samples. The mean capsanthin content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 118.11, 117.61, 116.74, 116.05 ASTA units compared to the lower values of 116.32, 116.22, 115.27, 114.45 ASTA units respectively in open sun dried samples, irrespective of treatments. Ramakrishnan and Francis (1973) showed that the major colour

changes in dried chilli was due to the production of brown pigments due to high temperature and Malliard reaction. Similar results have been depicted by Anonymous (2005), Schweiggert *et al.* (2005), Jyothi *et al.* (2008) and Naima *et al.* (2013).

5.2.1.5 Reducing sugar (%)

Pre-treatments, methods of drying and storage influenced significantly ($p \leq 0.05$) the reducing sugar content in chilli samples. At the completion of drying process, the reducing sugar content of solar tunnel dried samples at 0 days of storage was significantly higher than open sun dried samples in all treatments. The reducing sugar content of pre treated sun dried samples varied from 0.583 to 0.591% db. However control samples recorded the reducing sugar content of 0.582% db. The reducing sugar content recorded in open sun dried samples using pre-treatment T₇ was maximum 0.591% db followed by (0.590% db) in samples pretreated with T₆solution. The reducing sugar content of pretreated samples dried under solar tunnel drier ranged from 0.613 to 0.617% db. Control samples recorded reducing sugar content of 0.611% db. The chilli samples dried by solar tunnel drying at 0 days of storage using pre-treatment T₇ had a maximum reducing sugar content of 0.617% db which was found at par with samples pretreated with T₆solution.

Higher mean reducing sugar content values at all sampling dates were observed in solar tunnel dried samples (0.533% db) compared to (0.511% db) in open sun dried samples irrespective of pretreatments and storage period. The reducing sugar content of chilli samples decreased during storage significantly in all samples. The mean reducing sugar content of solar tunnel dried samples at 30, 60, 90 and 120 days of storage was 0.574, 0.546, 0.487, 0.441% db compared to the lower values of 0.563, 0.514, 0.464, 0.425% db respectively in open sun dried samples, irrespective of treatments. It is suggested that the degradation of reducing sugar during storage is attributed to the formation of browning compounds resulting by the reaction of sugars and amino acids (Kyung *et al.*, 2012). The chilli

dried by solar drying method had a reducing sugar of 0.533 per cent and chilli dried by sun drying method 0.511 per cent. The results were in close proximity with Joy *et al.* (2001), Mangaraj *et al.* (2001), Lee *et al.* (2004), Sadhna and Bharti (2005) and Wiriya *et al.* (2009).

5.2.1.6 Non-Enzymatic Browning

Pre-treatments are widely used to control browning as they inhibit enzymatic browning by acting as reacting with intermediates in the Malliard reaction leading to prevention of pigmentation (Arora and Bharti, 2005). At the completion of drying process, the non enzymatic browning values of open sun dried samples at (0) days of storage was significantly higher than solar tunnel dried samples in all treatments. The non-enzymatic browning values recorded in open sun dried samples without any pre-treatment was maximum 0.150 at 0 days of storage where as the non-enzymatic browning values of pre-treated samples varied from 0.146 to 0.149. Minimum non-enzymatic browning value of (0.146) was recorded in samples dried by using T₇ as pre-treatment solution followed by 0.146 in T₆ pretreated samples. The non-enzymatic browning value of chilli samples at the completion of solar tunnel drying at (0) days of storage was maximum (0.125) in control samples and a lower value of 0.123 to 0.125 was recorded in pre-treated samples. Minimum non-enzymatic browning values of (0.123) was recorded in samples which were dried after using T₇ as pre-treatment followed by 0.124 in T₆ pretreated samples.

Browning is a major factor contributing to quality loss in foods. The change in colour is important for determining dried product quality (Lee *et al.*,1991). The non enzymatic browning values of chilli samples increased significantly during storage in all samples. Higher mean non enzymatic browning values were observed in open sun dried samples (0.167) compared to (0.135) in solar tunnel dried samples irrespective of pretreatment and storage. The mean non enzymatic browning values of sun dried samples at 30, 60, 90 and 120 days of storage were 0.162, 0.168, 0.177, 0.181 compared to the lower values of 0.130,

0.136, 0.141, 0.146 respectively in solar tunnel dried samples, irrespective of treatments. Pigment oxidation and decomposition, due to the higher exposure of oxygen when an intensive vaporization take place on the surface of chilli was the reason of increase in NEB during storage (Topuz and Ozdemir, 2004).

Similar results are observed by Ahmad and Shivare (2001), Jasim and Shivare (2001), Gupta *et al.* (2002), Kumari *et al.* (2003).

5.2.1.7 Colour values (L^* , a^* , b^*) in Sun dried chilli

The L^* value of treated samples at (0)day varied from 28.07 to 30.52 compared to minimum (L^*) value of 27.65 in untreated samples. Maximum a^* value of 24.23 was recorded in samples pretreated with T_7 solution at (0) days of storage. The a^* values recorded after 120 days of storage varied from 19.50 to 22.59 in treated samples compared to a^* value of 19.13 in control samples. The untreated samples had b^* value of 11.78, whereas treated samples have b^* values of 11.87 to 12.68. Maximum b^* value of 12.68 was recorded in samples pretreated with T_7 solution at (0) days of storage. The untreated samples had c value of 24.74, whereas treated samples have c values of 24.96 to 27.35. The (c) values recorded after 120 days of storage varied from 21.98 to 25.44 in treated samples compared to (c) value of 22.60 in control samples. The (h) values recorded after 120 days of storage varied from 27.4 to 29.90 in treated samples compared to (h) value of 29.90 in control samples. Maximum h value was observed in control samples. The ΔE values recorded after 120 days of storage varied from 0.591 to 4.733 in treated samples compared to L^* value of 0.000 in control samples. The decrease in $L^*a^*b^*$ is due to the formation of browning compounds. The results are in close proximity with Shivare *et al.* (1981), Shrivastava *et al.* (1990), Aleksandra and Biserka (2004), Naima *et al.* (2013).

5.2.1.8 Colour values (L^* , a^* , b^*) in solar tunnel dried chilli

Maximum L value of 31.56 was recorded in samples pretreated with T_7 solution at (0) days of storage. The L values recorded after 120 days of storage

varied from 27.51 to 30.20 in treated samples compared to L value of 27.03 in control samples. The untreated samples had a^* value of 22.81 at (0) days of storage whereas treated samples have a^* values of 23.01 to 25.23. The untreated samples had b^* value of 12.50, whereas treated samples have b^* values of 12.62 to 13.44. Maximum b^* value of 13.44 was recorded in samples pretreated with T_7 solution at (0) days of storage. The c values recorded after 120 days of storage varied from 23.63 to 23.67 in treated samples compared to c value of 23.30 in control samples. The untreated samples had h value of 28.70 which is found at par with samples pretreated with T_1 solution, whereas treated samples have h values of 28.00 to 28.70. Maximum h value of 30.10 was recorded in control at 120 days of storage. The ΔE values recorded after 120 days of storage varied from 0.606 to 4.748 in treated samples compared to L value of 0.000 in control samples. Maximum ΔE value was observed in samples pretreated with T_7 solution.

Similar results are observed by Zhan (1996), Shrivastava *et al.* (1990), Hossain and Bala (2002) and Weerachai *et al.* (2002).

5.3 Experiment No. 2: Effect of pre-treatments, mechanical drying temperatures and storage period on quality of chillies (Kashmir Long-1)

5.3.1 Physico-chemical characteristics of dried chilli

5.3.1.1 Moisture content (%)

At the completion of drying process, the moisture content of chilli samples dried at 45°C at 0 days of storage was significantly higher than samples dried at 55° and 65 °C in all treatments. The moisture content recorded in chilli samples dried at 45°C without any pre-treatment was maximum 11.10% db where as the moisture content of pre-treated samples varied from 10.15 to 10.94% db. Minimum moisture content (10.15% db) was recorded in samples dried by using T_7 as pre-treatment solution followed by 10.27% db in samples pretreated with T_6 solution. The moisture content of chilli samples at the completion of mechanical drying at 55°C was maximum (10.22% db) in control samples and a lower values

of 9.09 to 10.06% db was recorded in pre-treated samples. Minimum moisture (9.09% db) was recorded in samples which were dried after using T₇ as pre-treatment followed by 9.27% db in samples dried using T₆ as pretreatment. The moisture content of chilli samples at completion of drying at 65°C (at 0 days of storage) was maximum (9.87% db) in control samples and a lower value of 8.72 to 9.70% db was recorded in pre-treated samples. Minimum moisture (8.72% db) was recorded in samples which were dried after using T₇ as pre-treatment followed by 8.90% db in samples pretreated with T₆ solution. Wiriya *et al.* (2009) reported the higher drying temperatures for long period resulted in a rapid loss of moisture. Therefore higher temperature recorded lower moisture and vice-versa.

The mean moisture content of chilli samples dried at 45°C after 30, 60, 90 and 120 days of storage were 11.15, 11.45, 11.58, 11.67% db compared to the lower values of 10.33, 10.58, 10.78, 10.87% db in samples dried at 55°C and further lower values of 9.93, 10.17, 10.36, 10.45% db in samples dried at 65°C, irrespective of pretreatments. Higher mean moisture content values during 120 days of storage were observed in chilli samples dried at 45°C (11.29% db) compared to chilli dried at 55°C (10.44% db) and lower values in chilli samples dried at 65°C (10.04% db), respectively. During storage progression the moisture increases because dried chilli absorbs moisture from air. The results are in close proximity with Joy *et al.* (2001), Mangaraj *et al.* (2001), Weerachai *et al.* (2002), Lee *et al.* (2004), Sadhna and Bharti (2005) and Satyanarayana and Vengaih (2010).

5.3.1.2 Ascorbic acid (mg/100g db)

During mechanical drying operation there was reduction in ascorbic acid of chilli samples which was influenced significantly ($p \leq 0.05$) by pre-treatments, methods of drying and storage. The ascorbic acid content of pre treated samples varied from 53.21 to 55.51 mg/100g db at (0) days of storage. However control samples recorded the minimum ascorbic acid content of 53.20 mg/100 g db. The maximum ascorbic acid content of 55.51 mg/100g db was recorded in chilli

samples dried at 45°C using pre-treatment T₇, followed 55.21 mg/100g db in samples pretreated with T₆ solution. The pretreated chilli samples had ascorbic acid content in range of 49.12 to 50.87 mg/100g db and control samples recorded 49.07 mg/100g db ascorbic acid. The chilli samples dried at 55°C at (0) days of storage using pre-treatment T₇ had a maximum ascorbic acid content of 51.12 mg/100g db followed by 50.87 mg/100g db in samples pretreated with T₆ solution. The ascorbic acid content of pretreated samples dried at 65°C ranged from 40.95 to 42.44 mg/100g db and control samples recorded 40.95 mg/100g db ascorbic acid at (0) days storage. The chilli samples dried at 65°C at 0 days of storage using pre-treatment T₇ had a maximum ascorbic acid of 42.65 mg/100g db followed by T₆ (42.44 mg/100g db). Vega *et al.* (2008) reported that the air drying method had a detrimental effect on the retention of the ascorbic acid. This was because heated air inherently exposes the product to oxidation thus reducing their ascorbic acid content.

The ascorbic acid content of chilli samples decreased significantly during storage in all samples. The mean ascorbic acid of chilli dried at 45°, 55° and 65°C at 30, 60, 90 and 120 days of storage was 53.53, 53.14, 52.20, 51.81 mg/100g db compared to the lower values of 49.41, 49.10, 48.28, 47.92 mg/100g db and 41.21, 40.95, 40.26, 39.96 mg/100g db, irrespective of treatments. Higher mean ascorbic acid values at all sampling dates were observed in chilli samples dried at 45°C (52.91 mg/100g db) compared to chilli dried at 55°C (48.87 mg/100g db) and chilli samples dried at 65°C (40.76 mg/100g db), respectively. During storage ascorbic acid oxidizes into L-dehydroascorbic acid and due to light and temperature (BeMiller and Whistler, 1996).

The results are in close proximity with Ahmad and Shivare (2001), Jasim and Shivare (2001), Eleyinmi *et al.* (2002), Gupta *et al.* (2002), Kumari *et al.* (2003), Wiriya *et al.* (2009) and Satyanarayana and Vengaih (2010).

5.3.1.3 Capsaicin (%)

Capsaicin content of the fruit is an important constituent determining the pungency of chillies. Pungency of chilli is an important quality parameter which is due to the mixture of 7 homologous branched chain alkyl vanillyl amides namely capsiacinoids (Hoffman *et al.*, 1883). The capsaicin content of pre-treated samples dried at 45°C varied from 0.954 to 1.094% db at (0) days of storage. The control samples recorded the capsaicin content of 0.922% db. The capsaicin content recorded in chilli samples dried at 45°C using pre-treatment T₇ was maximum 1.094% db followed 1.082% (db) in samples pretreated with T₆ solution. The pretreated chilli samples dried at 55°C had capsaicin content in range of 0.724 to 0.775% db at (0) days of storage and control samples recorded 0.716% db capsaicin content. The chilli samples dried at 55°C at 0 days of storage using pre-treatment T₇ had a maximum capsaicin content of 0.775% db followed by 0.766% db in samples pretreated with T₆ solution. The capsaicin content of pretreated samples dried at 65°C ranged from 0.629 to 0.716% db at (0) days of storage and control samples recorded 0.615% db capsaicin content. The chilli samples dried at 65°C at 0 days of storage using pre-treatment T₇ had a maximum capsaicin content of 0.716% db followed 0.678% db in samples pretreated with T₆ solution.

. The capsaicin content of chilli samples decreased significantly during storage in all treatments. The mean capsaicin content of chilli samples dried at 45°, 55° and 65°C at 30, 60, 90 and 120 days of storage were 0.976, 0.931, 0.898, 0.873% db compared to the lower values of 0.705, 0.667, 0.634, 0.573% db and 0.621, 0.587, 0.557, 0.538% db, respectively, irrespective of treatments. Higher mean capsaicin content values at all sampling dates were observed in chilli samples dried at 45°C (0.940% db) compared to chilli dried at 55°C (0.665% db) and chilli dried at 65°C (0.592% db), respectively.

Loss of capsaicin and dihydro-capsaicin is a problem in preparation and storage of dehydrated pepper. Low storage temperature improved retention of capsiacinoids (Wang *et al.*,2009). Similar results were observed by Pura *et al.* (2001), Eleyinmi *et al.* (2002), Ayhan *et al.* (2009), Wiriya *et al.* (2009), Manjula *et al.* (2011) and Kwanhathai *et al.* (2012).

5.3.1.4 Capsanthin (ASTA Units)

The capsanthin content of pre treated samples dried at 45°C varied from 126.93 to 127.52 ASTA units at (0) days of storage. However control samples recorded the capsanthin content of 126.73 ASTA units. The capsanthin content recorded in chilli samples dried at 45°C using pre-treatment T₇ was maximum 127.72 ASTA units at (0) days of storage followed by 127.52 ASTA units in samples pretreated with T₆ solution. The pretreated chilli samples dried at 55°C had capsanthin content in range of 126.75 to 127.32 ASTAunits at (0) days of storage whereas, control samples recorded capsanthin content of 126.57 ASTA units at 0 days of storage. The chilli samples dried at 55°C at 0 days of storage using pre-treatment T₇ had a maximum capsanthin content of 127.57 ASTA units followed by 127.32 ASTA units in T₆ pretreated samples. The capsanthin content of pretreated chilli samples dried at 65°C ranged from 126.52 to 127.44 ASTA units at (0)days of storage whereas, control samples recorded capsanthin content of 126.32 ASTA units. The chilli samples dried at 65°C using pre-treatment T₇ had a maximum capsanthin content of 127.44 ASTA units at (0) days of storage followed by samples pretreated with T₆ solution as 127.21ASTA units. It was observed by Kim *et al.* (2004) that ASTA colour values were found better in modified method (mechanical) of drying as compared to the conventional method (sun and solar) of drying.

The capsanthin content of chilli samples decreased significantly during storage in all samples. The mean capsanthin content of chilli samples dried at 45°, 55° and 65°C irrespective of pretreatments at 30, 60, 90 and 120 days of storage were 127.17, 126.60, 126.06, 125.13 ASTA units compared to the lower values

of 126.97, 126.38, 125.84, 124.79 ASTA units and 126.73, 126.19, 125.54, 1224.50 ASTA units, irrespective of treatments. Higher mean capsanthin content values at all sampling dates were observed in chilli samples dried at 45°C (126.44 ASTA units) compared to chilli dried at 55°C (126.21 ASTA units) and chilli dried at 65°C (125.97 ASTA units), respectively. Similar decline in ASTA in dried chilli was observed by Jasim and Shivare (2001), Kimet *et al.* (2004), Suna *et al.* (2006), Ljubo *et al.* (2007) and Sankrit and Nantawan (2009). The pretreatment combinations recorded maximum ASTA because of protecting the samples against oxidation and other chemical reactions forming browning compounds.

5.3.1.5 Reducing sugar (%)

The reducing sugar content of pre treated samples dried at 45°C at (0) days of storage varied from 0.599 to 0.614%. However control samples recorded the reducing sugar content of 0.594% db. The reducing sugar content recorded in chilli samples dried at 45°C using pre-treatment T₇ was maximum 0.614% db at par with samples pretreated with T₆ solution at (0) days of storage. The pretreated chilli samples dried at 55°C at (0) days of storage had reducing sugar content in the range of 0.541 to 0.543% db and control samples recorded 0.541% db reducing sugar content. The chilli samples dried at 55°C at 0 days of storage using pre-treatment T₇ had a maximum reducing sugar content of 0.543% db at par with T₆ pretreated samples. The reducing sugar content of pretreated samples dried at 65°C at (0) days of storage ranges from 0.511 to 0.513% db whereas, control samples recorded reducing sugar content of 0.510%. The chilli samples dried at 65°C at 0 days of storage using pre-treatment T₇ had a maximum reducing sugar content of 0.513% db at par with T₆ pretreated samples.

Remarkable difference in reducing sugar depicted a decreasing trend of reducing sugar (%) during storage progression. The reducing sugar content of chilli samples decreased significantly during storage in all samples. The mean reducing sugar content of chilli dried at 45°, 55° and 65°C at 30, 60, 90 and 120

days of storage was 0.566, 0.538, 0.480, 0.434% db compared to the lower values of 0.507, 0.481, 0.430, 0.389% db and 0.478, 0.454, 0.406, 0.367% db, respectively, irrespective of treatments. This decrease is attributed to formation of browning compounds due to the non-enzymatic browning reaction known as Malliard reaction. Higher mean reducing sugar content values at all sampling dates were observed in chilli samples dried at 45⁰C (0.525% db) compared to chilli dried at 55⁰C (0.470%db) and chilli dried at 65⁰C (0.444% db) , respectively, irrespective of pretreatments and storage periods.

The findings are in close proximity to that observed by Ramakrishnan and Francis (1973), Ljubo *et al.* (2007), Wiriya *et al.* (2009) and Ajaykumar *et al.* (2012).

5.3.1.6 Non-Enzymatic Browning (OD at 420nm)

The non-enzymatic browning values recorded in chilli samples dried at 45⁰C without any pre-treatment was maximum 0.241 where as the non-enzymatic browning values of pre-treated samples varied from 0.111 to 0.239. Minimum non-enzymatic browning value of 0.111 was recorded in samples dried by using T₇ as pre-treatment solution followed by 0.120 in samples pretreated with T₆ solution. The non-enzymatic browning value of chilli samples at the completion of drying at 55⁰C was maximum (0.344) in control samples and a lower value of 0.298 to 0.343 was recorded in pre-treated samples at (0) days of storage. Minimum non-enzymatic browning value (0.298) was recorded in samples which were dried after using T₇ solution as pre-treatment followed by 0.299 in T₆ pretreated samples. The non-enzymatic browning of chilli samples at the completion of drying at 65⁰C was maximum (0.504) in control samples and a lower value of 0.374 to 0.502 was recorded in pre-treated samples at (0) days of storage. Minimum non-enzymatic browning (0.374) was recorded in samples which were dried after using T₇ as pre-treatment followed by 0.461 in T₆ pretreated samples. The non-enzymatic browning values varied significantly with different treatment combinations. Non-enzymatic reactions increase in rate at

higher temperatures and at intermediate moisture levels. This reaction is a diffusion controlled binary reaction between amino acid and reducing sugar. It produces colour important for flavour but in dried chilli it's a negative attribute because it decreases colour (Ljubo *et al.*,2007).

The non-enzymatic browning of chilli samples increased during storage significantly in all samples. The mean non-enzymatic browning values of chilli samples dried at 45, 55 and 65°C at 30, 60, 90 and 120 days of storage were 0.275, 0.295, 0.394, 0.437 compared to the lower values of 0.358, 0.419, 0.485, 0.564 and 0.484, 0.519, 0.573, 0.655, irrespective of treatments. The mean non-enzymatic browning values during 120 days of storage were observed in chilli samples dried at 45°C (0.319) compared to higher values in chilli samples dried at 55°C (0.428) and chilli samples dried at 65°C (0.541) , respectively, irrespective of pretreatments and storage days.

Similar results were reported by Hayam *et al.* (1997), Howard *et al.* (1994), Fairfield *et al.* (2002), Suna *et al.* (2006) and Vega *et al.* (2008),

5.3.1.7 Colour values (L*, a*, b*) in chilli dried at 45°C

Maximum L value of 31.81 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had a* value of 23.46, whereas treated samples have a* values of 23.67 to 25.95. Maximum a* value of 25.95 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had b* value of 13.55, whereas treated samples have b* values of 13.68 to 14.57. Maximum b* value of 14.57 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had c value of 27.09, whereas treated samples have c values of 27.34 to 29.76. Maximum c value of 29.76 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had h value of 30.00 which is found at par with samples pretreated with T₁ solution, whereas treated samples have h values of 29.30 to 30.00. Maximum h value of 30.70 was recorded in control at

120 days of storage. The ΔE values recorded after 120 days of storage varied from 0.620 to 4.919 in treated samples compared to ΔE value of 0.000 in control samples. Maximum ΔE value was observed in samples pretreated with T₇ solution.

With storage the decrease in $L^*a^*b^*$ is attributed to the formation of browning compounds. The results are in close proximity with Park and Lee (1975), Minguez *et al.* (1994), Ibrahim and Mehmet (2002), Ljubo *et al.* (2007) and Kwanhathai *et al.* (2012).

5.3.1.8 Colour values (L^* , a^* , b^*) in chilli dried at 55°C

The L^* values recorded after 120 days of storage varied from 27.05 to 29.96 in treated samples compared to L^* value of 26.58 in control samples. Maximum L^* value was observed in samples pretreated with T₇ solution. The untreated samples had a^* value of 21.14, whereas treated samples have a^* values of 21.33 to 23.38. Maximum a^* value of 23.38 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had b^* value of 11.67, whereas treated samples have b^* values of 11.78 to 12.42. Maximum b^* value of 12.42 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had c value of 24.15, whereas treated samples have c values of 24.37 to 26.47. Maximum c value of 26.47 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had h value of 28.90 which is found at par with samples pretreated with T₁ solution, whereas treated samples have h values of 28.00 to 28.90. Maximum h value of 29.90 was recorded in control which is found at par with samples pretreated with T₁ solution at 120 days of storage. The ΔE values recorded after 120 days of storage varied from 1.361 to 5.100 in treated samples compared to ΔE value of 0.000 in control samples. Maximum ΔE value was observed in samples pretreated with T₇ solution. The results were in close proximity with those of Ramakrishnan and Francis (1973), Park and Lee (1975), Suna *et al.* (2006) and Ljubo *et al.* (2007).

5.3.1.9 Colour values (L*, a*, b*) in chilli dried at 65°C

The untreated samples had L* value of 26.92, whereas treated samples have L* values of 27.95 to 29.60. Maximum L* value of 29.60 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had a* value of 20.33, whereas treated samples have a* values of 20.51 to 23.57. Maximum a* value of 23.57 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had b* value of 12.25, whereas treated samples have b* values of 12.30 to 13.56. Maximum b* value of 13.56 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had c value of 23.74, whereas treated samples have c values of 23.97 to 27.19. Maximum c value of 27.19 was recorded in samples pretreated with T₇ solution at (0) days of storage. The untreated samples had h value of 31.10, whereas treated samples have h values of 29.90 to 31.00. Maximum h value of 31.10 was recorded in control at 120 days of storage. The ΔE values recorded after 120 days of storage varied from 0.773 to 5.592 in treated samples compared to ΔE value of 0.000 in control samples. Maximum ΔE value was observed in samples pretreated with T₇ solution. Similar results are observed by Ibrahim and Mehmet (2002), Ljubo *et al.* (2007) and Kwanhathai *et al.* (2012).

5.4 Experiment No. 3: Effect of packaging materials and storage period on quality attributes of chilli powder

The best pre-treatment T₇ (25 g Potassium Carbonate + 10 ml ground nut oil + 1 g gum acacia + 0.01 g BHA per litre for (15 min.)) dip time the samples were samples were dried under sun, solat tunnel drier at 45 °C powder was made from samples and stored in three packaging materials was carried over for experiment No. 3. No other pre-treatment was studied further.

5.4.1 Physico-chemical characteristics of dried chilli powder

5.4.1.1 Moisture content (%)

The moisture content of chilli powder prepared from chilli dried under sun, solar tunnel drier and mechanical drier at 45°C was 9.19, 9.14 and 9.10% (db) respectively at 0 days of storage. During storage of 120 days there was significant increase in moisture content in all chilli powder samples due to drying method, packaging material and storage period. In LDPE pouches maximum mean moisture content of 9.29% (db) was recorded in chilli powder prepared from sun dried chillies during 120 days of storage, followed by 9.23% (db) in chilli powder prepared from solar tunnel dried chillies whereas, minimum moisture content 9.21% (db) was observed in chilli powder prepared from mechanical dried chillies. An increase in moisture content during 120 days of storage was also observed in chilli powder samples when packed in MLP pouches. The maximum mean moisture content of 9.27% db was recorded during 120 days of storage in chilli powder prepared from sun drying, followed by 9.22% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum moisture content of 9.16% (db) in chilli powder samples prepared from mechanical dried chillies. Among the packages used for storage studies of chilli powder samples, vacuum packaged MLP pouches indicated lowest increase in moisture content throughout 120 days of storage. The mean moisture content of 9.21%(db) was recorded during 120 days of storage in chilli powder prepared from sun dried chillies followed by 9.16% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum moisture content of 9.12% (db) in chilli powder prepared from mechanical dried chillies. Irrespective of methods of drying of chillies the mean moisture content during 120 days of storage was recorded in chilli powder packed in LDPE pouches was 9.24%(db) followed by 9.22% (db) in chilli powder samples packed in MLP pouches. The minimum moisture content of 9.16%db was recorded in vacuum packaged MLP pouches samples. It is observed that, there was a difference in the moisture content of chilli powder obtained from three

drying methods. This difference is attributed to generation of high temperature during grinding of chillies (Mallappa *et al.* 2015)

Since chilli powder is highly hygroscopic in nature and can cause moisture gain from air and result in quality loss of dried powder during storage progression. Vacuum packaging prevents the air to cause moisture gain hence acts as the best packaging material for storing chilli powder (Hayam *et al.*,1997).

Similar results were reported by Thompson (1994), Fairfield *et al.* (2002), Howard *et al.* (2000) and Ou *et al.* (2002).

5.4.1.2 Ascorbic acid (mg/100g db)

Ascorbic acid is degraded by higher temperatures and the degradation product (L dehydroascorbic acid, DHAA) could participate in Strecker degradation with amino acid, producing a browning pigment. Not only does the high temperature of drying air affect the loss of ascorbic acid, but a long period of drying time can also introduce a significant loss of ascorbic acid(Mallappa *et al.* 2015 ; Kwanhathai *et al.* 2012)

During storage of 120 days there was significant decrease in ascorbic acid (mg/100g db) of all chilli powder samples due to method of drying, packaging material and storage. The maximum mean ascorbic acid content of 45.79mg/100g (db) during 120 days of storage was recorded in mechanical dried chilli powder samples packed in LDPE pouches followed by 31.92 mg/100g (db) in solar tunnel dried chilli powder samples whereas, minimum ascorbic acid 31.23 mg/100g (db) was observed in chilli powder prepared from sun drying packed in LDPE pouches. A decrease in ascorbic acid during 120 days of storage was also observed in chilli powder packed in MLP pouches.

The maximum mean ascorbic acid 46.12mg/100g db was recorded during 120 days of storage in chilli powder prepared from mechanical drying, followed by 32.33 mg/100g db in chilli powder samples prepared from solar tunnel dried chillies and minimum ascorbic acid of 31.40mg/100g in sun dried samples.

Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest decrease in ascorbic acid throughout 120 days of storage. The maximum mean ascorbic acid of 46.92 mg/100g (db) was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 32.59 mg/100g (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum ascorbic acid of 32.07 mg/100g db in chilli powder prepared from sun dried chillies. Irrespective of methods of drying of chillies the minimum mean ascorbic acid during 120 days of storage was recorded in LDPE packed samples was as 36.31 mg/100g (db) followed by 36.62 mg/100g (db) in chilli powder samples packed in MLP pouches. The maximum ascorbic acid content of 37.19 mg/100g (db) was recorded in vacuum packaged samples.

The air drying temperature and oxygen had a detrimental effect on the retention of ascorbic acid and heated air and oxygen inherently exposes the products to oxidation, reducing their ascorbic acid content (Howard *et al.*, 2000). Similar results have been reported by Pura *et al.* (2001), Ou *et al.* (2002), Marin *et al.* (2004), Sidonia *et al.* (2005) and Suna *et al.* (2006).

5.4.1.3 Capsaicin (%db)

The capsaicin content of chilli powder prepared from chillies dried under sun, solar tunnel drier and mechanical drier at 45°C was 0.70, 0.74, 0.90% (db) respectively at 0 days of storage. During storage of 120 days there was significant decrease in capsaicin content of all chilli powder samples. In LDPE pouches the maximum mean capsaicin content of 0.82%(db) during 120 days of storage was recorded in mechanically dried samples followed by 0.70%(db) in solar tunnel dried chilli powder samples, whereas, minimum capsaicin content of 0.65%(db) was observed in chilli powder prepared from sun drying packed in LDPE pouches. A decrease in capsaicin content during 120 days of storage was also observed in chilli powder samples when packed in MLP pouches. The maximum mean capsaicin content of 0.83% (db) was recorded during 120 days of storage in chilli

powder prepared from mechanically dried chillies, followed by 0.71% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum capsaicin content of 0.64% (db) in sun dried samples. Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest decrease in capsaicin content throughout 120 days of storage. The maximum mean capsaicin content of 0.85% (db) was recorded during 120 days of storage in chilli powder prepared from mechanical drier, followed by 0.72% (db) in chilli powder samples prepared from solar tunnel dried chillies and minimum capsaicin content of 0.66% db in sun dried samples. Irrespective of methods of drying of chillies, the minimum mean capsaicin content during 120 days of storage was recorded in LDPE packed samples as 0.72% (db) followed by 0.73% (db) in chilli powder samples packed in MLP pouches. The maximum capsaicin content of 0.74% (db) was recorded in vacuum packaged samples. Same results have been observed Pura *et al.* (2001), Kirschbaum-Titze *et al.* (2002a), Ou *et al.* (2002), Marin *et al.* (2004), Sidonia *et al.* (2005) and Suna *et al.* (2006).

5.4.1.4 Capsanthin (ASTA Units)

The ASTA colour value is mainly attributable to the carotenoids (Kim *et al.*, 2004), the colour loss may be related to function of browning compounds since red pepper contains considerable amounts of reducing sugars and amino acids. Gopalakrishna and Babylatha (2000) showed that a major colour change in red pepper during drying was due to the large increase in the brown pigments. The capsanthin content of chilli powder prepared from chillies dried under sun, solar tunnel drier and mechanical drier at 45°C was 121.44, 122.58, 132.03 ASTA units respectively at 0 days of storage. During storage of 120 days there was significant decrease in capsanthin content of all chilli powder samples. In LDPE pouches the maximum mean capsanthin content of 130.90 ASTA units during 120 days of storage was recorded in powder prepared from mechanically dried chillies followed by 121.14 ASTA units in solar tunnel dried chilli powder samples, whereas, minimum capsanthin content of 120.05 ASTA units was observed in

chilli powder prepared from sun drying and packed in LDPE pouches. A decrease in capsanthin content during 120 days of storage was also observed in chilli powder samples packed in MLP pouches. The maximum mean capsanthin content 129.93 ASTA units was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 119.36 ASTA units in chilli powder samples prepared from solar tunnel dried chillies and minimum capsanthin content of 118.75 ASTA units in powder prepared from sun dried chillies. Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest decrease in capsanthin content throughout 120 days of storage. The maximum mean capsanthin content 132.38 ASTA units was recorded during 120 days of storage in chilli powder prepared from mechanically dried chillies, followed by 123.69 ASTA units in chilli powder samples prepared from solar tunnel dried chillies and minimum capsanthin content of 121.41 ASTA units in chilli powder prepared from sun dried chillies. Irrespective of methods of drying of chillies, the minimum mean capsanthin content during 120 days of storage was recorded in LDPE packed samples as 124.03 ASTA units followed by 122.68 ASTA units in chilli powder samples packed in MLP. The maximum capsanthin content of 125.83 ASTA units was recorded in vacuum packaged samples.

This loss in the colour was also observed by Krishnamurthy and Natarajan (1973), Mahadevaiah *et al.* (1976), Pura *et al.* (2001), Marin *et al.* (2004), Reilly *et al.* (2005) and Sidonia *et al.* (2005).

5.4.1.5 Non-Enzymatic Browning

The non-enzymatic browning values of chilli powder prepared from chilli dried under sun, solar tunnel drier and mechanical drier at 45°C was 0.092, 0.088, 0.060 respectively at 0 days of storage. During storage of 120 days there was significant increase in non-enzymatic browning values of all chilli powder samples. In LDPE pouches the maximum mean non-enzymatic browning value of 0.205 during 120 days of storage was recorded in chilli powder prepared from sun

dried samples followed by 0.123 in chilli powder prepared from solar tunnel dried chillies whereas, minimum non-enzymatic browning value of 0.103 was observed in chilli powder prepared from mechanically dried chillies.

An increase in non-enzymatic browning during 120 days of storage was also observed in chilli powder samples obtained from sun, solar tunnel drier and mechanical drier when packed in MLP pouches. The maximum mean non-enzymatic browning value of 0.172 was recorded during 120 days of storage in chilli powder prepared from sun dried chillies, followed by 0.105 in chilli powder samples prepared from solar tunnel dried chillies and minimum non-enzymatic browning value of 0.093 in chilli prepared from mechanical dried chillies. Among the packages used for storage studies of chilli powder samples, vacuum packaging indicated lowest increase in non-enzymatic browning values throughout 120 days of storage. The mean non-enzymatic browning value of 0.134 was recorded during 120 days of storage in chilli powder prepared from sun drying, followed by 0.091 in chilli powder samples prepared from solar tunnel dried chillies and minimum non-enzymatic browning value of 0.079 in chillies prepared from mechanically dried chillies. Irrespective of methods of drying of chillies the maximum mean non-enzymatic browning values during 120 days of storage was recorded in LDPE packed samples as 0.144 followed by 0.123 in chilli powder samples packed in MLP. The minimum non-enzymatic browning value of 0.101 was recorded in vacuum packaged samples.

Lee *et al.* (2004) suggested that using high temperatures for drying air results in the dark colour due to non-enzymatic browning reactions. At low temperature of drying without excessive heating particularly on product surface prevents forming dark brown colour. Therefore at a lower drying air temperatures a better quality powder can be produced.

The findings are in close proximity to that observed by Jasim and Shivare (2001), Kimet *et al.* (2004), Suna *et al.* (2006) and Sankrit and Nantawan (2009).

5.4.1.6 L*, a*, b*,c, h and ΔE

Undesirable changes in the colour may lead to decrease in quality and marketing value of chilli powder. Therefore, the surface colour of the pepper is an important criterion. Loss of red colour is caused by auto oxidation of carotenoids. The stability of the carotenoids during storage has been shown to depend on drying conditions with the rate of deterioration increasing as the drying temperature increases (Figen and Mustafa, 2001). The powder prepared mechanically at 45°C had highest L*, a*, b*, c, h values followed by solar tunnel dried samples and sun dried samples. At (0) days of storage maximum L*, a*, b*, c, h values recorded in mechanically dried chilli powder were 32.19, 32.62, 39.01, 50.85, 50.10 followed by 31.82, 31.71, 38.81, 50.12, 50.70 in solar tunnel dried samples, and minimum 30.17, 30.10, 37.02, 47.71, 50.90 in sun dried samples. The L value after 120 days of storage varied from 31.96 to 32.05. During 120 days of storage the maximum mean L*, a*, b*,c, h and ΔE values recorded in mechanically dried, vacuum packaged chilli powder samples were 32.05, 32.26, 38.83, 50.37, 50.34, 0.59 followed by 30.96, 32.13, 38.72, 50.32, 50.30, 0.61 in mechanically dried, chilli powder packed in MLP pouches. The mean minimum L*, a*, b*,c, h and ΔE values recorded were 31.90, 32.07, 38.06, 49.76, 49.92, 1.01 chilli powder packed in LDPE pouches .

The maximum mean L*, a*, b*,c, h and ΔE values during 120 days of storage recorded in solar tunnel dried, vacuum packaged chilli powder samples were 31.23, 31.07, 49.22, 50.84, 1.28 followed by 31.13, 30.98, 37.96, 48.99, 50.78, 1.32 in solar tunnel dried chilli powder packed in MLP pouches. The minimum mean L*, a*, b*,c, h and ΔE values recorded were 31.04, 30.86, 37.83, 48.82, 50.78, 1.17 in chilli powder packed in LDPE pouches. The maximum mean L*, a*, b*,c, h and ΔE values during 120 days of storage recorded in sun dried, vacuum packaged chilli powder samples were 29.76, 29.79, 37.07, 47.55, 51.22, 0.76 followed by sun dried chilli powder packed in MLP pouches as 29.67, 29.67, 36.89, 47.34, 51.08, 0.67 and the minimum mean L*, a*, b*,c, h and ΔE values

recorded were 29.63, 29.60, 36.48, 46.85, 51.34, 0.80 chilli powder packed in LDPE pouches.

The results are in close proximity with those of Hayam *et al.* (1997), Kaleemullah and Kailappan (2004), Suna *et al.* (2006), Pal *et al.* (2008) Vega *et al.* (2008) and Mallappa *et al.* (2015).

5.4.1.7 Moisture sorption isotherms

The moisture sorption isotherms describe relationship between water activity and the equilibrium moisture content for a food product at constant pressure and temperature. These help in the optimization of process such as design, packaging and processing problems for modeling moisture changes which occur during drying, it also help in predicting shelf life stability (Figen and Mustafa, 2001).

The sun dried powder had an initial moisture content of 9.14 percent and aw of 0.16 which increased during 120 days of storage. The mean values of moisture content and aw recorded after 120 days of storage were maximum (9.34 percent and 0.534) in chilli powder samples packed in LDPE pouches followed by 9.25 percent and 0.511 in chilli samples packed in MLP pouches and minimum moisture content 9.23 percent and 0.405 recorded in vacuum packaged chilli powder samples. The solar tunnel dried chilli powder samples had an initial moisture content of 9.19 per cent and aw 0.14 which increased during 120 days of storage. The maximum moisture content and aw values recorded were 9.36 percent and 0.513 in samples packed in LDPE pouches followed by 9.23 percent and 0.491 in samples packed in MLP pouches and minimum moisture content of 9.21 percent and 0.389 in vacuum packaged samples. The mechanical dried chilli powder samples had an initial moisture content of 9.10 per cent and aw 0.13 which increased during 120 days of storage. The maximum moisture content and aw values recorded were 9.33 percent and 0.498 in samples packed in LDPE pouches followed by 9.16 percent and 0.475 in samples packed in MLP pouches

and minimum moisture content of 9.13 percent and 0.375 in vacuum packaged samples.

Among the packaging materials used, minimum changes in moisture content and water activity were observed in vacuum packaged chilli powder samples followed by MLP and LDPE packaged samples. Similar results have been observed by Hayam *et al.* (1997), Kaleemullah and Kailappan (2004), Ljubo *et al.* (2007), Pal *et al.* (2008) and Vega *et al.* (2008).

5.5 Drying studies

5.5.1 Sun and solar tunnel drying

Pre treatments had exercised profound influence on final moisture content of chilli samples. At the end of 84 hour of sun drying un treated samples had maximum moisture content of 14.45% db compared to lower moisture content of 10.94 to 13.65% db in treated samples. Samples pre treated with T₇ solution had 10.43% db moisture at the end of 83 hour followed by 10.94% and 11.43% db recorded after 84 hour in samples pre treated with T₆ and T₅ solution respectively. Un-treated samples in solar tunnel dryer possessed moisture content of 13.43% db after 60 hours of drying compared to 10.19 to 12.75% db moisture content recorded in pre treated chillies with T₆ to T₁ solution. Minimum moisture content of 9.85% db after 8 hours was recorded in samples pre treated with T₇ solution.

5.5.2 Mechanical drying

At 45 °C un treated samples took 36 hours to reach to final moisture content of 11.10% db where as treated samples took 26.33 to 34 hours to dry to 10.15 to 10.94%db. Chillies pre treated with T₇ solution took 26.33 hours at 45 °C to attain a moisture content of 10.15% db followed by samples pre treated with T₆ solution which attained a moisture content of 10.27% db after 28 hours of drying at 45 °C. Un treated chilli samples dried at 55 °C took 19 hours to attain a moisture content of 10.22%db , where as, pre treated samples took 16 to 18 hours to attain a moisture content of 9.09 to 10.06% db. Minimum time of 16 hours was

required to dry pre treated chillies at 55 °C for attaining minimum moisture content of 9.09% db followed by chilli samples pre treated with T₆ solution which took 16.16 hours to attain final moisture content of 9.27% db. At 65 °C untreated chilli samples took 10 hours to attain moisture content of 9.87% db whereas it took 7 to 9 hours for pre treated samples to attain moisture content of 8.72 to 9.70% db. Chilli samples pre treated with T₇ solution took 7 hours to dry to a moisture content of 8.72% db followed by 8.90% db recorded in T₆ treated samples after 7.66 hours.

5.6 Drying kinetics

Fig. 1 to 4 show the variation in drying behaviour of chillies at three different temperatures and sun and solar drying. Results from Fig. 2 shows that upto 0.1 moisture decreases linearly and afterwards it decreases in non-linear fashion. Khazaei *et al.* (2008) reported the dependence of drying kinetics on air temperature, air velocity, material size, drying time etc. the data clearly shows the dependence of drying time on temperature. Samples dried at higher temperatures have shorter drying times because of higher drying force and vice-versa (Leeratanarak *et al.*, 2006 and Doymaz, 2011) increased temperatures increase the amount of water content removed thus decreasing the time required to draw out moisture from sample. Internal moisture migration is increased by increasing heat flux. Hassini *et al.* (2002) has figured the effect of increasing temperature on the activity of water along with the influence on the moisture diffusion coefficient and the enthalpy of vaporization of the product.

The decrease in moisture content may be attributed to the availability, orientation and bonding of water molecules in food sample. Initially heat is taken by the sample to heat it and evaporate only some portion of the free moisture, in the beginning heat provided by the source takes the moisture out from the surface and as the drying advances the moisture moves out by diffusion. The heat penetrates inside and knocks the moisture out leaving a product with decreased moisture content. In the beginning drying rate increases owing to the availability

of free moisture. With increasing drying temperatures the amount of moisture removed from the samples increased and the time duration required to achieve drying decreased. As the water content decreases due to evaporation, more and more moisture moves out to the surface by diffusion and thereby further decreasing the amount of water to be evaporated while leads to decline in the drying rate. At last the water molecules which are strongly bound, are to be removed by the heat supplied. At this point, kinetic energy of molecules increases due to which temperature of air substance equals which decrease the drying rate and finally brings it to an end.

Similar findings have also been reported by Kaleemullah and Kailappan (2004), Vega *et al.* (2007).

5.6.1 Kinetic modeling

Three models namely Page Model, Newton Model, Hundeson-Pabis Model were used to evaluate our data. The observed data was fitted in the given models equations. The drying constants were estimated using these model equations. The drying constants were estimated using these model equations. Drying constants ranged widely in 3 models. The empirical drying constants for chillies and co-efficient of determination (R^2) at each temperature are given in Table 26. The selection of the best model to describe the drying behaviour of chillies is based on the highest co-efficient of determination (R^2) and lowest Chi-square (χ^2) and Root Mean Square Error (RMSE). The page model showed the highest R^2 values ranging from 0.989 to 0.993. Highest R^2 values of Page model imply that this equation fits the data best. The Chi-square (χ^2) and RMSE in page model showed a range of 0.00024 to 0.00149 and 0.0127-0.0372. The observations clearly show that page model fits the data best. In other words page model describes best the drying characteristics of chillies.

Similar findings have also been reported by Ibrahim *et al.* (1997), Ibrahim and Mehmet (2002), Vega *et al.* (2008).

5.6.2 Drying Characteristics of sun, solar tunnel and mechanical drying at (45, 55 and 65°C)

The characteristics of dried chillies (Kashmir Long-1) showed in Table 28(a,b,c,d,e) depicted that best pretreated chilli samples dried under sun, solar and mechanically dried, the sun dried sample had initial weight of the chilli sample was 500 gm which was reduced to 118.34 gm after 84 hours of drying. The average moisture content decreased from 441.46 to 15.27% db. At the beginning the drying rate and MR was 0 and 1, the drying rate varied from 1.685 to 5.014 and MR decreased from 1 to 0.0676. However the completion of solar tunnel drying took 48 hours which showed a decrease in weight from 500 to 133.33 gm. The initial average moisture content recorded was 436.86% db which was reduced to 39.72% db after 48 hours of drying. The drying rate varied from 0 to 1.8395 and MR decreased from 1 to 0.1042. The time taken by the chilli samples to dry at mechanical drying of chillies carried out at 45, 55 and 65°C was 1680 minutes (28 hours), 900 minutes (15 hours) and 420 minutes (7 hours) respectively. The decrease in weight of chillies dried at 45°C was from 500 to 402 gm. However in chillies dried at 55 and 65°C the decrease in weight ranged from 500 to 141.67 gm and 350 to 128.34 gm respectively. The average moisture content decrease from 441.45 to 23.91% db; 424.91 to 53.52% db and 410.85 to 77.29% db respectively in chilli dried at temperatures of 45, 55 and 65°C. The drying rate varied from 0 to 0.00088 and MR decreased from 1 to 0.10589 at 45°C. In 55 and 65°C the drying rate varied from 0 to 0.01616 and 0 to 0.0611 and MR decreased from 1 to 0.1246 at 55°C and 1 to 0.2264 at 65°C.

Chapter – 6

SUMMARY AND CONCLUSION

The present investigation entitled, “Effect of drying methods and packaging materials on storage stability and quality of chillies” was carried out in the Food Processing Laboratory of Division of Post Harvest Technology, SKUAST (K) Shalimar to study the effect of various pre-treatments, drying methods and storage on quality of dried chilli cv. Kashmir Long 1. Dried chilli powder produced by using the best pre-treatment combination was stored under ambient conditions in metallised laminated polyesterpouches (MLP), low density polyethylene pouches (LDPE) and vacuum packaged MLP pouches. The physico-chemical analysis of chilli samples was recorded at 0, 30, 60, 90, 120 days of storage. The drying models were fitted to data and water activity studies carried out. The results are summarized as under:

1. Physical parameters recorded revealed that freshly harvested red chilli had an average length of 11.21 cm, average breadth of 1.57 cm, average fruit weight of 9.060 g, while as seed content was 34 per cent. It contained ascorbic acid of 49.4 mg/100g, per cent reducing sugar (0.64%), moisture (80.68%), 0.38 per cent Capsaicin and 98.37 ASTA units capsanthin. The fresh chillies had L^* , a^* , b^* values of 32.666, 20.913, 35.805 respectively
2. Statistically significant effect of pre-treatments and drying methods was observed on moisture content (%db) in dried chilli samples. The moisture content recorded in open sun dried samples without any pre-treatment was maximum 14.45% db whereas the moisture content of pre-treated samples varied from 10.43 to 13.65% db. Minimum moisture content (10.43% db) was recorded in samples dried by using T_7 as pre-treatment solution followed by 10.94% db in samples pre-treated with T_6 solution. The moisture content of chilli samples at the completion of solar tunnel drying

was maximum (13.43% db) in control samples and a lower value of 9.85 to 12.75% db was recorded in pre-treated samples. Irrespective of drying methods, pre-treated chillis with T₇ and T₆ solution recorded minimum moisture content of 10.83 and 11.58% respectively during 120 days of storage compared to maximum value of 14.78% in control samples.

3. The pre treatments, drying methods and storage had a significant influence on retention of ascorbic acid content of dried chilli samples. The ascorbic acid content of pre treated sundried samples varied from 38.70 to 39.98 mg/100g db at (0) days of storage and control samples recorded the ascorbic acid content of 38.52 mg/100 g db. Maximum ascorbic acid content of 39.98 mg/100g was recorded in sun dried samples pretreated with T₇ solution. The ascorbic acid content of pretreated solar tunnel dried samples at (0) days of storage ranged from 39.62 to 41.08 mg/100g db and control samples recorded 39.47 mg/100g db ascorbic acid.
4. Pretreatments and methods of drying had significant effect on capsaicin content (%) of whole dried chilli samples during storage. Irrespective of drying methods, maximum capsaicin content of 0.940% db and 0.926% db respectively was recorded during 120 days of storage in chilli samples pre-treated with T₇ and T₆ solution compared to lower values of 0.847% db in untreated samples. Maximum mean capsaicin content of 0.938% db was recorded during storage in solar tunnel dried chilli samples compared to lower value of 0.840% db in sundried chilli samples.
5. Pretreatments, drying methods and storage period influenced significantly the capsanthin content of dried chilli samples. Irrespective of methods of drying the maximum mean capsanthin content of 119.62 and 119.40 ASTA units was observed in chilli samples pretreated with T₇ and T₆ solution respectively compared to 113.61 ASTA units in control samples. Solar tunnel dried samples had maximum capsanthin content in all sampling dates compared to sundried samples. The overall capsanthin

content of 120.69 ASTA units was recorded in solar tunnel dried samples compared to 118.55 ASTA units in sun dried samples.

6. The pre-treatments, drying methods and storage period influenced the reducing sugar content of chilli samples. Irrespective of drying methods maximum reducing sugar content 0.518 to 0.526% db was recorded in pre-treated samples compared to 0.516% db in control. Among the drying methods, chilli samples dried under solar tunnel drier possessed higher mean value reducing sugar of 0.536%db compared to 0.516%db in sun dried samples.
7. The pre-treatments and storage influenced the non-enzymatic browning of chilli samples significantly, whereas method of drying did not influence the NEB values significantly. Irrespective of methods of drying OD values for NEB were maximum 0.153 for control samples while as pre-treated samples with T₇solution has OD values of 0.149.
8. The L*, a*, b*, c values were significantly influenced by the pre-treatments and storage in sun dried chilli samples. During 120 days of storage minimum L* value was recorded in control samples as 26.84 whereas pre-treated samples exhibited higher values of 27.26 to 29.84. Maximum L* values of 29.84 and 29.23 were recorded in samples pre-treated with T₇ and T₆ solution respectively. The a* values recorded in sun dried control samples was 20.45 and the pre-treated samples possessed maximum a* values in range of 20.74 to 23.39. The b* values recorded in sun dried control samples during 120 days of storage was 11.36 compared to higher values of 11.4 to 12.16 recorded in samples dried by using pre-treatment's. The c values of sun dried chilli samples were minimum 23.504 during 120 days of storage where as higher c values 23.586 to 26.364 were recorded in pre-treated samples.
9. The L*, a*, b*, c values were significantly influenced by the pre-

treatments and storage in solar tunnel dried chilli samples. During 120 days of storage minimum L^* value was recorded in control samples as 27.86 whereas pre-treated samples exhibited higher L^* values of 28.28 to 30.87. Maximum L^* values of 30.87 and 30.26 were recorded in samples pre-treated with T_7 and T_6 solution respectively. The a^* values recorded in solartunnel dried control samples was 21.47 and the pre-treated samples possessed maximum a^* values in range of 21.76 to 24.41. The b^* values recorded in solartunnel dried control samples during 120 days of storage was 12.09 compared to higher values of 12.16 to 12.92 recorded in samples dried by using pretreatments. The c values of solar tunnel dried chilli samples were minimum 24.66 in untreated samples during 120 days of storage where as higher c values 24.92 to 27.02 were recorded in pre-treated samples.

10. The pre-treatments, drying temperatures and storage influenced the moisture content of mechanically dried chilli samples significantly. The mean maximum moisture content (11.05%db) during 120 days of storage irrespective of drying temperatures was recorded in untreated samples, whereas, lower moisture content values 10.16 to 10.90% db, were recorded in pre-treated samples. Minimum moisture content values 10.16 and 10.32% db respectively were recorded in samples pre-treated with T_7 and T_6 solution. Irrespective of pre-treatments samples dried at higher drying temperatures i.e. 65° and 55°C had lower moisture content of 10.04 and 10.44%db respectively, compared to the higher moisture content of 11.29%db recorded in samples dried at 45°C .
11. The pre treatments, drying temperatures and storage had a significant influence on retention of ascorbic acid content of dried chilli samples. The mean maximum ascorbic acid content (46.91 to 48.94 mg/100g db) was recorded in pretreated samples and minimum ascorbic acid content of 46.88 mg/100g db were recorded in untreated samples. Maximum ascorbic

acid content of 48.94 and 48.66 mg/100g respectively were recorded in samples pre-treated with T₇ and T₆ solution. Irrespective of pre-treatments dried samples at higher drying temperatures i.e. 65 and 55°C had lower mean ascorbic acid content of 40.76 and 48.87 mg/100g respectively, compared to the higher ascorbic acid content of 52.91 mg/100g recorded in samples dried at 45 °C.

12. The pre-treatments, drying temperatures and storage had a significant influence on capsaicin content% db of dried chilli samples. The mean maximum capsaicin content (0.688 to 0.786% db) during 120 days of storage irrespective of drying temperatures was recorded in pretreated samples. Whereas, lower capsaicin content value 0.671%db, was recorded in untreated samples. Maximum capsaicin content values 0.786 and 0.774%db respectively were recorded in samples pre-treated with T₇ and T₆ solution. Irrespective of pre-treatments dried samples at higher drying temperatures i.e. 65 and 55°C had lower capsaicin content of 0.592 and 0.665%db respectively, compared to the higher capsaicin content of 0.940%db recorded in samples dried at 45°C.
13. The pre-treatments and storage had a significant influence on capsanthin content ASTA units of dried chilli samples. The mean maximum capsanthin content (125.82 to 126.83 ASTA units) during 120 days of storage irrespective of drying temperatures was recorded in pre-treated samples, whereas, lower capsanthin content value 125.61 ASTA units, was recorded in untreated samples. Maximum capsanthin content values 126.83 and 126.61 ASTA units respectively were recorded in samples pre-treated with T₇ and T₆ solution. Irrespective of pre-treatments dried samples at higher drying temperatures i.e. 65 and 55°C had lower capsanthin content of 125.97 and 126.21 ASTA units respectively, compared to the higher capsanthin content of 126.44 ASTA units recorded in samples dried at 45°C.

14. The pre-treatments and drying temperatures had a significant influence on reducing sugar content% db of dried chilli samples. The mean maximum reducing sugar content (0.476 to 0.484%db) during 120 days of storage irrespective of drying temperatures was recorded in pre-treated samples, whereas, lower reducing sugar content value 0.473%db, was recorded in untreated samples. Maximum reducing sugar content value 0.484%db respectively were recorded in samples pre-treated with T₇ which was found at par with T₆ solution. Irrespective of pre-treatments dried samples at higher drying temperatures i.e. 65 and 55°C had lower reducing sugar content of 0.444 and 0.470%db respectively, compared to the higher reducing sugar content of 0.525%db recorded in samples dried at 45°C.
15. The pre-treatments and drying temperatures had a significant influence on non-enzymatic browning values of dried chilli samples. The mean maximum non enzymatic browning value (0.469) during 120 days of storage irrespective of drying temperatures was recorded in untreated samples, whereas, lower non enzymatic browning values 0.362 to 0.465, were recorded in pre-treated samples. Minimum non enzymatic browning values 0.362 and 0.390 respectively were recorded in samples pre-treated with T₇ and T₆ solution. Irrespective of pre-treatments dried samples at higher drying temperatures i.e. 65 and 55°C had higher non enzymatic browning values of 0.541 and 0.428 respectively, compared to the higher non enzymatic browning value of 0.319 recorded in samples dried at 45 °C.
16. The L, a*, b*, c values were significantly influenced by the pre-treatments and storage in chilli samples dried at 45 °C. During 120 days of storage minimum L value was recorded in control samples as 28.08 whereas pre-treated samples exhibited higher values of 28.50 to 31.12. Maximum L* values of 31.12 and 30.50 were recorded in samples pre-treated with T₇ and T₆ solution respectively. The a* values recorded in chilli samples

dried at 45 °C control samples was 22.39 and the pre-treated samples possessed maximum a^* values in range of 22.69 to 25.46. The b^* values recorded in untreated chilli samples dried at 45 °C during 120 days of storage was 13.11 compared to higher values of 13.19 to 14.01 recorded in samples dried by using pretreatments. The (c) values of untreated chilli samples dried at 45 °C were minimum 25.94 during 120 days of storage where as higher c values 26.23 to 29.05 were recorded in pretreated samples.

17. The L^* , a^* , b^* , c values were significantly influenced by the pretreatments and storage in chilli samples dried at 55 °C. During 120 days of storage minimum L^* value was recorded in control samples as 27.07 whereas pre-treated samples exhibited higher values of 27.47 to 30.27. Maximum L^* values of 30.27 and 29.40 were recorded in samples pretreated with T_7 and T_6 solution respectively. The a^* values recorded in untreated chilli samples dried at 55 °C control samples was 20.17 and the pre-treated samples possessed maximum a^* values in range of 20.44 to 22.97. The b^* values recorded in untreated chilli samples dried at 55 °C during 120 days of storage was 11.40 compared to higher values of 11.51 to 12.37 recorded in samples dried by using pretreatments. The (c) values of untreated chilli samples dried at 55 °C were minimum 23.17 during 120 days of storage where as higher (c) values 23.46 to 25.55 were recorded in pretreated samples.
18. The L^* , a^* , b^* , c values were significantly influenced by the pretreatments and storage in chilli samples dried at 65 °C. During 120 days of storage minimum L^* value was recorded in control samples as 26.13 whereas pre-treated samples exhibited higher values of 26.52 to 28.96. Maximum L^* values of 28.96 and 28.38 were recorded in samples pretreated with T_7 and T_6 solution respectively. The a^* values recorded in untreated chilli samples dried at 65 °C was 19.40 and the pre-treated

samples possessed maximum a^* values in range of 19.66 to 23.12. The b^* values recorded in untreated chilli samples dried at 65 °C during 120 days of storage was 13.14 compared to higher values of 13.22 to 14.42 recorded in samples dried by using pretreatments. The (c) values of untreated chilli samples dried at 65 °C were minimum 23.44 during 120 days of storage where as higher (c) values 23.71 to 27.26 were recorded in pretreated samples.

19. The packaging material, drying method and storage influenced the moisture content of dried chilli powder samples significantly. The mean maximum moisture content (9.24%db) during 120 days of storage irrespective of drying methods was recorded in chilli powder samples packed in LDPE pouches, whereas, lower moisture content values 9.16 to 9.22%db, were recorded in chilli powder samples packed in vacuum packaged MLP pouches and MLP pouches. Irrespective of packaging materials dried chilli powder samples by drying methods i.e. sundried chilli, solar tunnel dried chilli had higher moisture content of 9.26 and 9.21% db respectively, compared to the lower moisture content of 9.16%db recorded in samples dried at 45 °C.
20. The packaging material, drying method and storage influenced the ascorbic acid content of dried chilli powder samples significantly. The mean maximum ascorbic acid content (37.19 mg/100g) during 120 days of storage irrespective of drying methods was recorded in chilli powder samples vacuum packaged in MLP pouches, whereas, lower ascorbic acid content values 36.62 and 36.31 gm/100g, were recorded in chilli powder samples packed in MLP pouches and LDPE pouches. Irrespective of packaging materials sundried chilli powder and solar tunnel dried chilli powder had lower ascorbic acid content of 31.57 and 31.72 mg/100g respectively, compared to the higher ascorbic acid content of 46.28

mg/100g recorded in chilli powder from mechanically dried samples at 45 °C.

21. The packaging material and drying method influenced the capsaicin content of dried chilli powder samples significantly. The mean maximum capsaicin content (0.74%db) during 120 days of storage irrespective of drying methods was recorded in chilli powder samples vacuum packaged in MLP pouches, whereas, lower capsaicin content values 0.73 and 0.72% db, were recorded in chilli powder samples packed in MLP pouches and LDPE pouches. Irrespective of packaging materials dried chilli powder samples prepared from sundried chilli and solar tunnel dried chilli had lower capsaicin content of 0.65 and 0.71%db respectively, compared to the higher capsaicin content of 0.83% db recorded in powder from mechanically dried chillies at 45 °C.
22. The packaging material and storage influenced the capsanthin content of dried chilli powder samples significantly. The mean maximum capsanthin content (125.83 ASTA units) during 120 days of storage irrespective of drying methods was recorded in chilli powder samples vacuum packaged in MLP pouches, whereas, lower capsanthin content values 122.68 and 124.03 ASTA units, were recorded in chilli powder samples packed in MLP pouches and LDPE pouches. Irrespective of packaging materials dried chilli powder samples prepared from sundried chilli and solar tunnel dried chilli had lower capsanthin content of 120.07 and 121.40 ASTA units respectively, compared to the higher capsanthin content of 131.07 ASTA units recorded in mechanically dried powder samples at 45 °C.
23. The packaging material, drying method and storage influenced the non-enzymatic browning values OD at 420 nm of dried chilli powder samples significantly. The mean maximum non-enzymatic browning values (0.144) during 120 days of storage irrespective of drying methods was recorded in chilli powder samples packed in LDPE pouches, whereas, lower non-

enzymatic browning values 0.101 and 0.123, were recorded in chilli powder samples packed in vacuum packaged MLP pouches and MLP pouches respectively. Irrespective of packaging materials dried chilli powder prepared from sundried chilli or solar tunnel dried chilli had higher non-enzymatic browning values of 0.170 and 0.106 respectively, compared to the lower non-enzymatic browning values of 0.092 recorded in samples dried at 45 °C.

24. The powder prepared mechanically at 45 °C. had highest L*, a*, b*, c, h values followed by solar tunnel dried samples and sun dried samples. At (0) days of storage maximum L*, a*, b*, c, h values recorded in mechanically dried chilli powder was 32.19, 32.62, 39.01, 50.85, 50.10 followed by 31.82, 31.71, 38.81, 50.12, 50.70 in solar tunnel dried samples and minimum 30.17, 30.10, 37.02, 47.71, 50.90 in sun dried samples. During 120 days of storage the maximum mean L*, a*, b*, c, h and ΔE values recorded in mechanically dried (45°C) vacuum packaged chilli powder samples were 32.05, 32.26, 38.83, 50.37, 50.34 and 0.59 followed by 30.96, 32.13, 38.72, 50.32, 50.30 and 0.61 in mechanically dried chilli powder packed in MLP pouches. The mean minimum L*, a*, b*, c, h and ΔE values recorded were 31.90, 32.07, 38.06, 49.76, 49.92 and 1.01 in chilli powder packed in LDPE pouches .
25. The sun dried chilli powder before packing in different packaging materials at (0) days of storage had an initial moisture content of 9.14 percent and aw of 0.16 which increased during 120 days of storage depending on packaging material used. The mean values of moisture content and aw recorded after 120 days of storage were maximum (9.34 percent and 0.534) in chilli powder samples packed in LDPE pouches followed by 9.25 percent and 0.511 in chilli samples packed in MLP pouches and minimum moisture content 9.23 percent and 0.405 recorded in vacuum packaged chilli powder samples. The solar tunnel dried chilli

powder samples had an initial moisture content of 9.19 per cent and aw 0.14 which increased during 120 days of storage. The maximum moisture content and aw values recorded were 9.36 percent and 0.513 in samples packed in LDPE pouches followed by 9.23 percent and 0.491 packed in MLP pouches and minimum moisture content of 9.21 percent and 0.389 in vacuum packaged samples. The mechanical dried chilli powder samples had an initial moisture content of 9.10 per cent and aw 0.13 which increased during 120 days of storage.

26. At the end of 84 hour of sun drying un treated samples had maximum moisture content of 14.45% db compared to lower moisture content of 10.94 to 13.65% db in treated samples. Samples pre treated with T₇ solution had 10.43% db moisture at the end of 83 hour followed by 10.94% and 11.43% db recorded after 84 hour in samples pre treated with T₆ and T₅ solution respectively. Un-treated samples in solar tunnel dryer possessed moisture content of 13.43% db after 60 hours of drying compared to 10.19 to 12.75% db moisture content recorded in pre treated chillies with T₆ to T₁ solution. Minimum moisture content of 9.85% db after 8 hours was recorded in samples pre treated with T₇ solution.
27. At 45 °C un treated samples took 36 hours to reach to final moisture content of 11.10% db where as treated samples took 26.33 to 34 hours to dry to 10.15 to 10.94%db. Chillies pre treated with T₇ solution took 26.33 hours at 45 °C to attain a moisture content of 10.15% db followed by samples pre treated with T₆ solution which attained a moisture content of 10.27% db after 28 hours of drying at 45 °C. Un treated chilli samples dried at 55 °C took 19 hours to attain a moisture content of 10.22%db , where as, pre treated samples took 16 to 18 hours to attain a moisture content of 9.09 to 10.06% db. Minimum time of 16 hours was required to dry pre treated chillies at 55 °C for attaining minimum moisture content of 9.09% db followed by chilli samples pre treated with T₆ solution which took

16.16 hours to attain final moisture content of 9.27% db. At 65 °C untreated chilli samples took 10 hours to attain moisture content of 9.87% db where as it took 7 to 9 hours for pre treated samples to attain moisture content of 8.72 to 9.70% db.

28. The selection of the best model to describe the drying behaviour of chillies is based on the highest co-efficient of determination (R^2) and lowest Chi-square (χ^2) and Root Mean Square Error (RMSE). The page model showed the highest R^2 values ranging from 0.989 to 0.993. Highest R^2 values of Page model imply that this equation fits the data best. The Chi-square (χ^2) and RMSE in pages model showed a range of 0.00024 to 0.00149 and 0.0127 - 0.0372. The observations clearly show that page model fits the data best. In other words page model describes best the drying characteristics of chillies.
29. The average moisture content decreased from 441.46 to 15.27% db. At the beginning the drying rate and MR was 0 and 1, the drying rate varied from 1.685 to 5.014 and MR decreased from 1 to 0.0676. However the completion of solar tunnel drying took 48 hours which showed a decrease in weight from 500 to 133.33 gram. The initial average moisture content recorded was 436.86% db which was reduced to 39.72% db after 48 hours of drying. The drying rate varied from 0 to 1.8395 and MR decreased from 1 to 0.1042. The time taken by the chilli samples to dry at mechanical drying of chillies carried out at 45, 55 and 65°C was 1680 minutes (28 hours), 900 minutes (15 hours) and 420 minutes (7 hours) respectively. The decrease in weight of chillies dried at 45°C was from 1500 to 402 gram.

Form the present studies it is concluded that the traditional method of sun drying chillies is unhygienic and is subjected to dust/ dirt and microbial contamination, rains during drying period which may spoil the whole lot. The drying time is long and quality of dried product is not superior with respect to

appearance and colour of pods.

The present investigation indicated that pre drying treatment of chillies with T₇ (2.5% Potassium Carbonate + 1% ground nut oil+ 0.1% gum acacia +0.001% BHA per litre (15 min.), T₆ (7.5% Potassium Carbonate + 2% ethyl oleate (5 min.) compared to control helped to reduce the drying time and maintained the quality parameters of whole chillies and chilli powder upto 120 days. Sun dried pre-treated chillies took 72 hours to dry to a moisture content of 10.43 to 13.65 percent compared to 84 hours taken for control samples. Solar tunnel drier provided a low cost drying alternative for drying chillies under hygienic conditions. The drier helped to reduce the drying time in comparison to sundried samples. Solar tunnel dried pre-treated samples took 48 hours to 60 hours to dry to moisture content of 9.85 to 13.43 percent.

Pretreated chilli samples dried mechanically at 45, 55, 65 °C indicated that drying time was reduced at 65 °C from 7 to 10 hours to a moisture content of 8.72 to 9.87 percent and at 55 °C it took 16 to 19 hours to reach a moisture content of 9.09 to 10.22 percent compared to 26.33 to 36 hours to reach a moisture content of 10.15 to 11.10 percent. The quality analysis during storage upto 120 days indicated retention of best quality parameters in samples at 45 °C.

The pre-treated chilli powder packed in vacuum pack after 120 days of storage had a moisture content of 9.15 percent, ascorbic acid content (47.09%), capsaicin (0.7%), capsanthin (131.55 ASTA units), NEB (0.093), L*, a*, b*, c, h, ΔE (31.84, 31.77, 38.56, 49.96, 50.50, 1.17), and water activity of 0.62.

Based on various model fitting criterion, the mechanical drying behaviour of whole chillies at 45, 55 and 65°C was found to comply page model, Newton model, Henderson-Pabis model.

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APPENDIX I**Standard weekly meteorological data during 2012**

Standard meteorological week	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
18	21.07	6.30	79.14	52.00
19	23.14	9.61	83.57	62.43
20	22.36	8.93	79.86	58.71
21	21.57	9.51	83.86	62.57
22	29.93	9.64	70.57	47.57
23	23.93	10.83	81.29	59.86
24	27.21	11.60	80.14	46.29
25	30.29	14.79	77.57	41.71
26	28.64	14.07	79.00	47.57
27	32.79	17.53	75.00	42.71
28	28.36	16.21	82.43	62.57
29	30.86	15.64	82.29	47.86
30	32.43	17.14	82.86	43.29
31	30.21	18.93	83.71	55.14
32	29.36	16.47	83.43	55.86
33	29.29	18.37	85.43	55.57
34	32.07	19.30	82.29	47.57
35	31.64	16.47	77.43	49.86
36	24.57	16.87	89.86	68.00
37	26.71	16.13	93.14	72.29
38	25.14	11.11	88.71	64.29
39	26.64	8.57	90.00	56.43

Standard weekly meteorological data during 2013

Standard meteorological week	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
18	21.00	7.14	80.14	51.43
19	21.79	9.50	88.29	57.14
20	26.21	8.86	76.00	41.00
21	27.14	12.07	76.57	49.43
22	26.57	8.69	77.00	41.29
23	31.86	14.10	73.00	46.71
24	25.21	15.61	91.00	66.71
25	31.14	14.50	72.00	40.00
26	29.10	17.61	81.00	52.14
27	31.23	17.40	78.57	45.86
28	29.00	16.43	81.57	51.43
29	31.14	18.31	74.29	48.57
30	32.71	18.47	71.86	44.14
31	30.50	19.27	79.71	56.29
32	32.07	19.13	77.14	47.00
33	21.74	16.86	90.14	84.00
34	30.36	17.07	75.29	62.57
35	28.64	15.97	83.86	60.57
36	29.57	13.39	79.57	51.71
37	23.79	13.57	86.86	67.29
38	28.93	9.04	81.00	48.00
39	28.21	11.67	85.29	63.43

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner, Dr. Rajkumari Koul, Professor, Division of Food Science and Technology, SKUAST, Jammu during Viva-Voce examination held on 8th of December, 2015 have been incorporated in the manuscript entitled, **“Effect of drying methods and packaging materials on storage stability and quality of chillies”** submitted by **Ms. Towseef Ahmad Wani (Regd. No. 2011-370-D)**.

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