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Influence of packaging material and storage temperature on colour quality and shelf life of red chilli powder

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ABSTRACT

Red chilli is an excellent source of bioactive compounds such as carotenoids, capsanthin, capsaicin, oleoresins, phenolics. These compounds impart red colour and pungency, important quality traits, to the chilli. Hence, present study was conducted to evaluate effect of packaging material and storage temperature on total extractable colour, oleoresin extractable colour and total carotenoid content of red chilli powder made from dried and destalked red chilli fruits. Chilli powder was packed in three different packaging material with and without vacuum at room (average annual temperature 25°C) and low (5±0.5°C) temperatures for 12 months. Results indicated that both packaging material and storage temperature significantly affected the total carotenoids and color quality of chilli powder in all the treatments at the end of 12 months. TCC in red chili powder stored in different packaging material at room and low temperature ranged from 261.52 to 250.62 mg/100 g and 261.52 to 259.14 mg/100 g, respectively The TEC and OEC for chilli powder packed in different packaging materials at room temperature conditions varied 262.87 to 247.44 ASTA units (Table 3-4). The content of TEC and OEC for chilli powder packed in different packaging material at low temperature ranged from 262.87 to 247.44 ASTA units. The chilli powder packed in polypropylene (PP), polypropylene vacuum (PPV), laminated (L) and laminated vacuum (LV) showed the least percent decline in colour quality parameters. Degradation rates were highest in powder packed in woven polypropylene (WPP). These samples were spoiled during sixth months of storage. Overall quality of red chilli powder was better in laminated pouch under vacuum than other packaging materials studied. Therefore vacuum packaging technology for long term storage of red chilli powder was found the best.

Keywords: *Capsicum annuum*, vacuum packaging, colour quality, total carotenoid content.

INTRODUCTION

The Capsicum genus includes thirty species, out of which, only five species such as *Capsicum annuum, Capsicum chinense, Capsicum frutescens, Capsicum baccatum and Capsicum pubescens* have been domesticated. Capsicum is cultivated either as pungent genotypes called chilli (hot pepper, paprika, american pepper, chile *etc*.) or non-pungent genotypes called sweet pepper (shimla mirch, bell pepper, capsicum *etc*.). Among pungent genotypes, chilli (*Capsicum annuum* L.) is an important spice crop in India. The crop is mainly grown in tropical, subtropical and temperate regions of the world. The world production of red chilli is estimated to be around 21 lakh tons and India shares about 45% of this quantity. In addition, India is the largest consumer and exporter of spices globally (Peter *et al*., 15). One of the major reasons behind wide popularity, demand and global acceptance of Indian chilli is its colour and pungency. Apart from this it is also an excellent source of capsanthin, capsaicin, oleoresins, carotenoids, phenolics and other important antioxidants which have proven pharmacological health benefits including antiinflammatory, antioxidant, anticarcinogenic and antiallergic activities (Maeda *et al*., 9; Nath *et al.,* 10). Literature reports that more than 40 different carotenoid pigments have been identified in chilli fruits including capsanthin, capsorubin and capsanthin 5, 6 epoxide (Davies *et al*., 5). Among antioxidants, carotenoids assume a unique biological function in humans associated with retinol equivalence and vitamin-A precursors, necessary for vision, growth, cell differentiation and other physiological processes (Nath *et al.,* 11). Capsanthin is known to exhibit antitumour activity, attenuates obesity induced inflammation and raises plasma HDL cholesterol levels (Maeda *et al*., 9). Ascorbic acid available in chilli acts as an aqueous reducing agent in biological systems and plays a significant role in preventing cancer, heart disease, cataract and immune system functioning (Perla *et al.,* 14). Chilli has immense medicinal potential due to the presence of carotenoids, total extractable colours, ascorbic acid and minerals. However, the nutritive value and phytochemical composition of chilli depends mainly on the colour, variety and stage of maturity (Howard *et al*., 7).

Colour and total carotenoid content are sensitive to the climate vagaries such as; temperature, humidity,

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moisture, oxygen, respiration rates, insects, pests and microorganisms. Oxidation of carotenoids and thereby colour change in dried red chilli is the major cause of its quality loss (Anderson and Lingnert, 2). In general, dry chillies are microbiologically safe having low moisture levels in comparison with fresh chillies but they are prone to oxidation and thus degradation. Presently, whole red chillies are being packed in gunny bags made of jute and stored the same way in retail outlets for distribution also from these red chillies its powder is being prepared. This practice results in the deprivation of carotenoids and colour quality due to oxidation. In addition, light acts as a catalyst during oxidation however, in complete absence of oxygen, light has little effect. Appropriate packaging material and packaging technique such as vacuum packaging may prove to be beneficial in addressing the loss of carotenoids and colour quality in red chilli and thereby maintaining the overall quality during longer storage periods. Hence present research work was undertaken to evaluate the efficacy of different packaging materials and storage temperatures in retaining the selected quality parameters such as moisture content, oleoresin, total extractable colour and total carotenoid content of chilli powder in acceptable range during longer storage period.

MATERIALS AND METHODS

In the present study whole red chillies (*var.* Local) were procured from local market of Abohar, Punjab. The whole red chillies with the initial moisture content of 12 ±1 °C were loaded in aluminum trays with the tray load of 0.30 g/cm^2 and air dried in a convective drier (MAC®, Macro scientific works®, Delhi, India) at 50 °C to a moisture level of 10±0.5% *(w.b.)*. The dried whole red chilli were cooled under shade at an ambient temperature followed by pulverization in a domestic blender (Morphy Richards, Bajaj Electricals Ltd., Mumbai, India) to yield homogenous powder. This powder was passed through the sieve shaker to obtain chilli powder with uniform particle size (157µm). Chilli powder was further subjected to three types of packaging material with and without vacuum and two types of storage conditions: 1) cold storage (temperature varied from 5±0.5°C); 2) room temperature (26±1°C). The three different packaging materials included *viz.*, polypropylene (PP), laminates (L), woven polypropylene (WPP) (Fig. 1). Around 250 g of chilli powder was kept for shelf life study in each packaging material.

Red chilli powder was vacuum packed (Sevana, 24SG034, 240 AC, 1900 W, India) in multilayer polythene pouches with 355×185×160 mm dimension. The observations on moisture content, total carotenoid content and colour quality in terms of total extractable colour and oleoresin extractable colour were recorded at an interval of one month and the shelf life study was carried out for twelve months.

The moisture content was determined by conventional oven drying method, using hot air oven

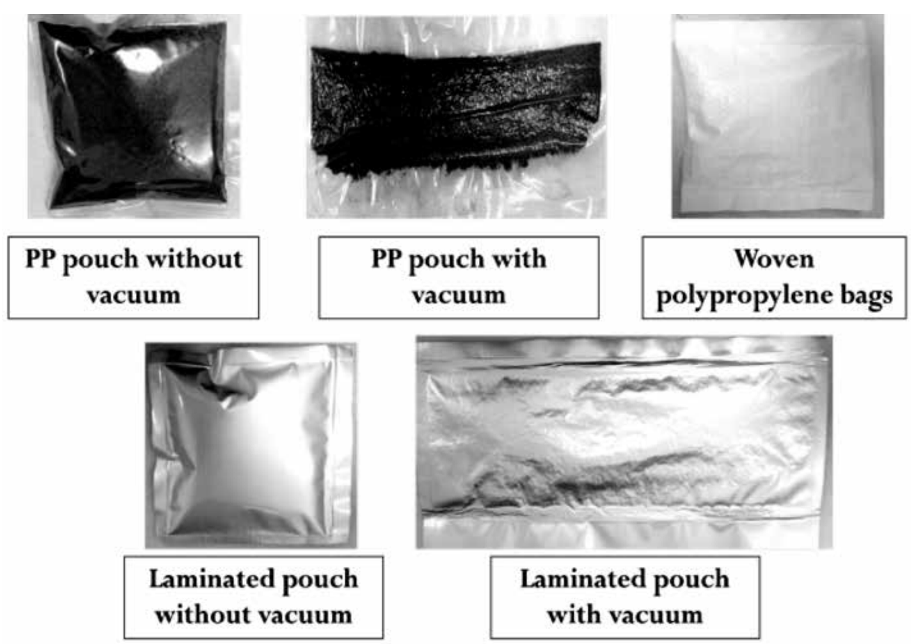

Fig. 1. Destalked red chilli powder packed in different packaging materials.

(M/s Popular Traders, Ambala, India). The samples were analysed individually in triplicate according to their respective standard protocols (AACC, 1).

Total carotenoid content (TCC) was determined by extracting the sample twice with acetone until the extract was colourless. The homogenate was filtered with suction through a Buchner funnel containing Whatman filter paper No.1 (Fisher Scientific, Pittsburg, PA). The filtrates were combined, transferred to separating funnel containing 50 ml of 4 % aqueous NaCl and 100 ml of petroleum ether (BP 40 to 60 °C). Absorption of the petroleum ether layer was measured at 470 nm in dim light using UV Vis spectrophotometer (M/s Civic Pharma, Chandigarh, India). A calibration curve was prepared for each group of samples using 99% pure β-carotene in the range of 10–100 µg per ml (Nath *et al.,* 12). The results were expressed as mg/100g.

The total extractable colour (TEC) or capsicum extractable colour in powder samples was measured as per the method 20.1 stipulated in the ASTA analytical methods (Chetti *et al*., 4). For this, 100 mg of chilli powder was diluted to volume with acetone in a 100 ml volumetric flask, shaken and then left to stand for 2 min. The flask was shaken vigorously and incubated at room temperature in dark for 16 h. After the incubation period, the flask was shaken again and left for sufficient time for particles to settle. The absorbance of the sample was recorded at 460 nm in UV–VIS dual beam spectrophotometer (M/s Civic Pharma, Chandigarh, India). The capsicum extractable colour was computed using the following formula and expressed as ASTA units.

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

The oleoresin extractable colour (OEC) in chilli powder was measured as per the procedure laid down in ASTA 20.1 analytical method (Chetti *et al*., 4). For this, 100 mg of chilli powder was diluted to volume with acetone in a 100 ml volumetric flask, shaken and then left to stand for 2 min. From this, 10 ml of the extract was pipetted into another 100 ml volumetric flask, diluted to volume with acetone and was then vigorously mixed. The absorbance of the sample was recorded at 460 nm in UV–VIS dual beam spectrophotometer (M/s Civic Pharma, Chandigarh, India). The oleoresin extractable colour was then determined as per the following formula and expressed as ASTA units.

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

All the physico-chemical parameters were measured in triplicate. Duncan's multiple range test (DMRT) and ANOVA were performed to evaluate the statistical differences in these parameters as affected by packaging materials and storage temperature. SPSS 16.0 software was used to conduct the DMRT and ANOVA tests. The significance was accepted at 5% levels of significance ($p<0.05$).

RESULTS AND DISCUSSION

Effect of packaging material and storage conditions on moisture content of red chilli powder is presented in Table 1. The data shows that there was no much variation in the moisture content of PP, PPV, L and LV packed samples during storage for 12 months though there was non-significant ($p<0.05$) decline with the advancement in the storage duration. The moisture content of red chilli powder ranged from 10.25 to 12.88 % and 10.25 to 18.55 % at room and low temperatures, respectively (Table 1). WPP packed chilli powder showed significant ($p<0.05$) variation with the advancement of storage duration. The moisture content in WPP increased from 10.25 % initially to 12.88 % at room temperature during the 12th month, in comparison to the samples stored in WPP at low temperature where the moisture content increased from 10.25 % to 18.55 % during the 5th month of storage followed by insect infestation thereafter. This might be explained on the basis of prevailing high humidity levels maintained in cold stores. From results, it is clearly evident that the change in moisture level was more perceptible for chilli powder stored at low temperature than room temperature.

During the 8th month of storage, WPP packed red chilli powder had the maximum moisture content of 13.66 % whereas at low temperature the moisture content after 5th month was 18.55 % which is due to variations in the moisture content of the sample and high relative humidity prevailing in the cold stores. On the contrary, the moisture content of PP, PPV, L and LV packaged chilli powder were not influenced by the storage condition i.e., it did not vary with room temperature, light or dark conditions or low temperature in cold storage. This was mainly attributed to the barrier properties of the packaging film. However, non-significant ($p<0.05$) differences were observed between PP, PPV, L and LV packed red chilli powder. Among these four packaging systems, it was observed that samples stored in laminates and laminates under vacuum were better as the samples were protected from light which might instigate oxidation of carotenoids and other colour quality parameters. In general, it was observed that the chilli powder packed under vacuum possess bright red mehroonish colour with characteristic pungency of capsaicin and no external debris thus indicating

Table 1. Effect of different packaging material and storage condition on moisture content of red chilli powder during storage.

Packing material	Storage Period (months)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Room storage (25°C)													
PP	10.25 ± 2.11b	10.28 ± 1.63b	10.29 ± 2.66b	10.30 ± 1.20b	10.45 ± 1.22b	11.21 ± 1.11c	10.88 ± 1.32c	11.23 ± 1.11c	11.46 ± 1.11c	11.58 ± 1.11c	11.63 ± 1.11c	11.70 ± 1.11c	11.77 ± 1.94c
PP V	10.25 ± 2.11b	10.25 ± 1.52b	10.26 ± 1.21b	10.32 ± 1.33b	10.40 ± 1.03b	11.58 ± 1.51c	10.88 ± 1.54c	11.23 ± 1.21c	11.56 ± 1.02c	10.78 ± 1.02b	10.26 ± 1.02b	10.55 ± 1.03b	10.30 ± 1.39b
L	10.25 ± 2.11b	10.25 ± 1.52b	10.25 ± 0.62b	10.28 ± 1.04b	10.29 ± 2.41b	10.32 ± 0.85b	10.33 ± 1.65b	10.41 ± 2.01b	10.45 ± 2.14b	10.20 ± 1.55b	10.26 ± 2.01b	10.22 ± 1.14b	10.26 ± 1.58b
LV	10.25 ± 2.11b	10.25 ± 1.52b	10.25 ± 1.02b	10.28 ± 2.01b	10.25 ± 2.15b	10.28 ± 2.04b	10.28 ± 2.11b	10.25 ± 1.31b	9.87 ± 0.84a	10.25 ± 1.33b	10.25 ± 1.98b	10.22 ± 2.04b	10.23 ± 0.95b
WPP	10.25 ± 2.11b	10.56 ± 1.36c	10.82 ± 0.95c	11.12 ± 0.98d	11.68 ± 2.54d	12.22 ± 1.92d	12.87 ± 2.51e	13.20 ± 1.00e	13.66 ± 3.10e	12.89 ± 1.05d	11.12 ± 1.44c	12.56 ± 1.09d	12.88 ± 2.16d
Cold storage (5°C)													
PP	10.25 ± 2.11b	10.30 ± 1.32b	10.35 ± 2.01b	10.44 ± 1.21c	10.56 ± 1.20c	11.22 ± 2.06c	11.40 ± 2.03d	11.56 ± 2.06c	11.94 ± 1.11c	12.23 ± 2.01d	12.38 ± 2.08d	12.55 ± 2.19d	12.85 ± 2.81d
PP V	10.25 ± 2.11b	10.26 ± 1.65b	10.26 ± 0.36b	10.33 ± 0.65b	10.33 ± 1.05b	10.48 ± 1.02b	10.38 ± 1.05b	10.12 ± 1.21b	10.36 ± 0.87b	10.28 ± 1.11b	10.26 ± 1.14b	10.25 ± 0.89b	10.26 ± 0.63b
L	10.25 ± 2.11b	10.25 ± 2.02b	10.25 ± 0.81b	10.28 ± 1.39b	10.26 ± 2.15b	10.30 ± 0.89b	10.30 ± 0.95b	10.37 ± 1.05b	10.40 ± 1.10b	10.20 ± 0.54b	10.26 ± 2.11b	10.22 ± 2.11b	10.28 ± 1.44b
LV	10.25 ± 2.11b	10.26 ± 2.50b	10.22 ± 1.22b	10.26 ± 1.54b	10.25 ± 2.32b	10.26 ± 2.14b	10.26 ± 0.87b	10.25 ± 1.22b	10.26 ± 1.22b	10.24 ± 1.09b	10.26 ± 1.14b	10.23 ± 1.11b	10.26 ± 1.33b
WPP	10.25 ± 2.11b	10.77 ± 1.77d	13.26 ± 1.64f	15.88 ± 2.02g	16.45 ± 3.14g	18.55 ± 2.01f	Sp	Sp	Sp	Sp	Sp	Sp	Sp

*PP: Polypropylene; PPV: Polypropylene vacuum; L: laminated; LV: Laminated vacuum; WPP: Wooven polypropylene; sp: spoiled
**Values with the same letters in a column are not significantly different at 5% level of significance.

no degradation at all. The variation in the moisture levels of the chilli powder was constant for vacuum packed bags irrespective of the storage temperature which again can be explained on the basis of its barrier properties.

Another quality parameter for dehydrated products is its rehydration capacity. It is the ability of a solid mass to absorb water and this capacity decreases with increasing length of storage duration. This reduction depends mainly on the extent of exposure to the external environment conditions *viz.,* light and oxygen levels. This exposure in vacuum packaging is least and hence the reduction in rehydrating capacity of the samples packed in vacuum is less as compared to the conventional packaging. This might be credited to the reduction of water binding sites due to chemical and structural changes in cells of the seed. Similar results were observed in mushroom by Kumar and Sreenarayanam, (8).

Carotenoids are the most potential bioactive compounds present in red chili, thus studying the retention of carotenoids and the pattern of their oxidation during storage is of prime importance. The experimental values of total carotenoid content of red chili powder in different packaging material and kept at different temperatures is presented in Table 2.

Both packaging material and storage temperature had a significant ($p<0.05$) impact on the retention of total carotenoids in all the treatments at the end of 12 months. A progressive decrease in TCC of chilli powder exposed to room temperature and cold storage conditions was observed. TCC in red chili powder stored in different packaging material at room and low temperature ranged from 261.52 to 250.62 mg/100 g and 261.52 to 259.14 mg/100 g, respectively (Table 2). A non-significant ($p<0.05$) decrease was observed in the TCC of samples stored in PP, PPV, L and LV at both room and low temperature. The TCC in PPV, L and LV was 258.91, 260.38 and 260.91 mg/100 g during 12th month of storage at room temperature. Significant ($p<0.05$) difference was observed between vacuum packed chilli bags and control (WPP). The TCC in WPP at room temperature was 250.62 mg/100 g during 12th month of storage whereas the samples were spoiled after 6th month at low temperature. This might be

Table 2. Effect of different packaging material and storage condition on total carotenoid content of red chilli powder during storage.

Packing material	Storage Period (months)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Room storage (25°C)													
PP	261.52 ± 21a	261.23 ± 21a	260.87 ± 14a	260.45 ± 21a	259.97 ± 14a	259.65 ± 15b	259.22 ± 14a	259.90 ± 19a	258.90 ± 14a	258.86 ± 17b	258.77 ± 14b	258.65 ± 09b	258.42 ± 07b
PP V	261.52 ± 21a	261.24 ± 24a	261.05 ± 25a	260.82 ± 15a	260.62 ± 12a	260.41 ± 21b	260.15 ± 15a	259.87 ± 22a	259.64 ± 21a	259.53 ± 12b	259.27 ± 16b	259.15 ± 14b	258.91 ± 14b
L	261.52 ± 21a	261.45 ± 15a	261.30 ± 21a	261.22 ± 16a	261.14 ± 21a	261.01 ± 22b	260.95 ± 24a	260.88 ± 16a	260.78 ± 24a	260.65 ± 15b	260.52 ± 21b	260.42 ± 08b	260.38 ± 15b
LV	261.52 ± 21a	261.50 ± 14a	261.45 ± 11a	261.39 ± 14a	261.32 ± 14a	261.28 ± 27b	261.20 ± 21a	261.15 ± 13a	261.10 ± 12a	261.06 ± 23b	261.01 ± 20b	260.94 ± 16b	260.91 ± 21b
WPP	261.52 ± 21a	260.63 ± 13a	259.35 ± 13a	259.12 ± 13a	258.86 ± 15a	258.45 ± 14b	258.02 ± 15a	257.45 ± 16a	256.41 ± 19a	254.33 ± 09a	253.15 ± 09a	252.45 ± 14a	250.62 ± 09c
Cold storage (5°C)													
PP	261.52 ± 21a	261.10 ± 14a	260.85 ± 14a	260.55 ± 21a	260.34 ± 21a	260.25 ± 11b	260.12 ± 14a	259.98 ± 14a	259.76 ± 17a	259.65 ± 11b	259.40 ± 11b	259.28 ± 11b	259.14 ± 11b
PP V	261.52 ± 21a	261.32 ± 21a	261.21 ± 15a	260.11 ± 11a	260.16 ± 14a	260.12 ± 13b	259.86 ± 16a	259.72 ± 18a	259.61 ± 21a	259.57 ± 14b	258.45 ± 18b	258.41 ± 17b	259.36 ± 18b
L	261.52 ± 21a	261.43 ± 14a	261.36 ± 21a	261.26 ± 14a	261.10 ± 16a	261.04 ± 14b	260.86 ± 24a	260.77 ± 21a	260.70 ± 22a	260.63 ± 09b	260.55 ± 21b	260.48 ± 08b	260.40 ± 14b
LV	261.52 ± 21a	261.52 ± 15a	261.48 ± 16a	261.45 ± 21a	261.40 ± 17a	261.36 ± 16b	261.33 ± 16a	261.30 ± 25a	261.27 ± 16a	261.22 ± 12b	261.18 ± 22b	261.15 ± 15b	261.11 ± 11b
WPP	261.52 ± 21a	260.11 ± 11a	258.14 ± 14a	257.45 ± 14a	256.58 ± 19a	255.45 ± 14a	Sp	Sp	Sp	Sp	Sp	Sp	Sp

*PP: Polypropylene; PPV: Polypropylene vacuum; L: laminated; LV: Laminated vacuum; WPP: Wooven polypropylene;; sp: spoiled
**Values with the same letters in a column are not significantly different at 5% level of significance.

due to prevailing high relative humidity in the cold stores. The deterioration was much faster in case of WPP than in vacuum packaging, the reason being the barrier property of the films used in vacuum packaging. Our findings are in agreement with the results of Deepa *et al.,* (6). These studies reported that loss in colour and other quality parameters were found at room temperature in comparison to low temperature. The deterioration of carotenoid pigments in chilli powder stored in WPP was more, probably due to higher oxidation and absorption of moisture from the surroundings.

Colour is the most important parameter from the standpoint of determining the quality characteristics in red chilli powder. Changes in the colour of a product could be used for the estimation of its shelf life. An attractive red colour is an important quality characteristic in red chilli powder. Table 3-4 shows that there was a general decline in the colour values for all the treatments. Significant ($p<0.05$) difference was observed in the colour values (TEC and OEC) for chilli powder stored for 12 months (Table 3-4).

During storage, it was observed that there was a general decline in the TEC and OEC for all the treatments irrespective of the storage temperatures. Samples appeared red initially and darken progressively with storage due to enhanced non-enzymatic browning. The changes were more prominent in chilli powder stored in WPP bags resulting in rapid deterioration while in vacuum packed chilli powder the decline was controlled. Since WPP packaging material does not possess barrier properties in comparison to laminates or polyfilms which are used in vacuum packaging. Also, oxidation of vulnerable compounds is enhanced at a relatively higher temperature resulting in rapid deterioration than storage at low temperature conditions. The double bond conjugated system in carotenoids gives brilliant red hues to chilli and this intense colour is the source of their susceptibility oxidation (Bunnell and Bauernfeind, 3).

The decrease in colour values during storage may be attributed to oxidation of carotenoid pigments (transformation of *trans*-β-carotene to *cis*-β-*carotene*)

Table 3. Effect of different packaging material and storage condition on total extractable colour of red chilli powder during storage.

Packing material	Storage period (months)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Room Storage (25°C)													
PP	352.17 ± 25a	351.85 ± 12a	351.20 ± 21a	350.74 ± 25a	350.21 ± 29a	350.01 ± 14a	349.65 ± 14a	348.56 ± 11a	347.82 ± 33b	346.12 ± 22a	346.00 ± 21b	345.92 ± 22b	345.88 ± 17b
PP V	352.15 ± 14a	352.00 ± 26a	351.75 ± 22a	351.26 ± 14a	350.85 ± 27a	350.33 ± 15a	349.82 ± 16a	349.15 ± 17a	348.69 ± 14b	348.26 ± 14b	348.10 ± 24b	347.89 ± 15b	347.41 ± 25b
L	352.16 ± 26a	352.10 ± 35a	351.74 ± 26a	351.52 ± 16a	351.12 ± 18a	350.82 ± 28a	350.52 ± 24a	349.86 ± 15a	349.52 ± 25b	349.02 ± 25b	348.84 ± 16b	348.41 ± 18b	348.11 ± 19b
LV	352.17 ± 25a	352.12 ± 21a	351.89 ± 24a	351.67 ± 19a	351.44 ± 14a	351.16 ± 19a	351.02 ± 15a	350.78 ± 24a	350.48 ± 14b	350.14 ± 32b	349.89 ± 31b	349.56 ± 18b	348.21 ± 29b
WPP	352.14 ± 45a	351.75 ± 15a	350.56 ± 29a	350.01 ± 28a	349.32 ± 32a	348.42 ± 28a	347.68 ± 35a	346.51 ± 25a	345.22 ± 32a	344.21 ± 14a	343.41 ± 22a	342.54 ± 12a	341.51 ± 21a
Cold storage (5°C)													
PP	352.17 ± 45a	352.10 ± 32a	351.87 ± 32a	351.22 ± 14a	351.10 ± 31a	350.84 ± 29a	350.50 ± 22a	350.15 ± 32a	348.75 ± 16b	348.23 ± 15b	348.02 ± 25b	347.60 ± 18b	347.26 ± 22b
PP V	352.16 ± 14a	352.10 ± 14a	351.88 ± 11a	351.52 ± 24a	351.20 ± 25a	350.87 ± 14a	350.41 ± 25a	349.86 ± 25a	349.46 ± 21b	349.13 ± 21b	349.00 ± 21b	348.85 ± 29b	348.66 ± 27b
L	352.16 ± 26a	352.15 ± 18a	352.01 ± 18a	351.78 ± 15a	351.35 ± 14a	350.78 ± 28a	350.42 ± 35a	350.03 ± 15a	349.68 ± 28b	349.26 ± 32b	349.06 ± 11b	348.88 ± 21b	348.60 ± 19b
LV	352.17 ± 58a	352.11 ± 27a	351.81 ± 25a	351.68 ± 24a	351.45 ± 26a	351.14 ± 11a	350.82 ± 15a	350.34 ± 11a	349.89 ± 14b	349.69 ± 11b	349.32 ± 21b	349.11 ± 25b	348.92 ± 21b
WPP	352.15 ± 14a	351.78 ± 29a	350.86 ± 14a	350.12 ± 17a	349.23 ± 28a	348.25 ± 17a	Sp	Sp	Sp	Sp	Sp	Sp	Sp

*PP: Polypropylene; PPV: Polypropylene vacuum; L: laminated; LV: Laminated vacuum; WPP: Wooven polypropylene; sp: spoiled
**Values with the same letters in a column are not significantly different at 5% level of significance.

and browning related to phenolic oxidation. The results are in agreement to the reports of Patras *et al.* (13) who reported lower *L** values in strawberry jam stored at higher temperature (15°C) in comparison to lower temperature (4°C) during storage. They also reported greater shift of *a** value, an indicator of redness, stored at 15°C compared to 4°C and thus resulted in a darker product.

The TEC and OEC for chilli powder packed in different packaging materials at room temperature conditions varied 262.87 to 247.44 ASTA units (Table 3-4). The content of TEC and OEC for chilli powder packed in different packaging material at low temperature ranged from 262.87 to 247.44 ASTA units (Table 3-4). Chilli powder samples stored at low temperature showed better colour retention however the difference observed was not significant ($p<0.05$). In addition, WPP packed red chilli powder stored at low temperature were infected with fungus due to high humidity levels maintained in the cold store. The samples also showed white patches on the surface with distinct odor. The carotenoids are sensitive to light and this sensitivity is also dependent upon the presence of oxygen and therefore light acts as a catalyst in inducing oxidation changes of the sensitive compounds like carotenoids (Bunnell and Bauernfeind, 3). Moisture serves the role of protecting carotenoids from oxidation through effect on free radicals produced during oxidation. Low moisture content in stored chilli powder samples in different packaging materials at different temperatures might be the reason for oxidation of carotenoids and thus lower colour values.

Dry chilli powder is microbiologically safe but faces *"oxidation"* related issues of carotenoid pigments. Packaging of chilli powder in WPP type bags aggravates this problem and results in heavy losses of carotenoid pigments and thus imparts poor colour quality. In this context, *vacuum packaging technology* has been found as a superior technology in preserving the quality of powder for up to 12 months when compared to WPP bags where chilli powder can be stored only for a short span of time. Vacuum packed chilli powder samples scored better on various

Table 4. Effect of different packaging material and storage condition on oleoresin extractable colour of red chilli powder during storage.

Packing material	Storage Period (months)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Room storage (25°C)													
PP	262.87 ± 11a	262.50 ± 17a	262.01 ± 20a	261.80 ± 21a	261.45 ± 11a	260.89 ± 21a	260.65 ± 14b	260.20 ± 21b	259.80 ± 21b	259.60 ± 19b	259.34 ± 22b	259.00 ± 21b	258.44 ± 11b
PP V	262.87 ± 09a	262.54 ± 18a	262.12 ± 31a	261.88 ± 17a	261.52 ± 25a	261.03 ± 25a	260.76 ± 15b	260.35 ± 18b	260.10 ± 25b	259.78 ± 14b	259.52 ± 14b	259.14 ± 15b	258.77 ± 16b
L	262.87 ± 21a	262.41 ± 22a	262.01 ± 21a	261.75 ± 18a	261.46 ± 14a	261.12 ± 15a	260.76 ± 24b	260.23 ± 19b	259.86 ± 14b	259.32 ± 15b	259.06 ± 15b	258.76 ± 20b	258.44 ± 21b
LV	262.87 ± 14a	262.62 ± 14a	262.55 ± 14a	262.34 ± 11a	262.22 ± 19a	262.14 ± 24a	261.08 ± 18b	261.00 ± 14b	260.90 ± 16b	260.81 ± 20b	260.72 ± 12b	260.63 ± 14b	260.40 ± 24b
WPP	262.87 ± 20a	261.25 ± 15a	260.53 ± 22a	258.45 ± 21a	257.56 ± 17a	256.25 ± 17a	255.35 ± 10a	253.54 ± 15a	252.21 ± 24a	250.14 ± 11a	249.11 ± 10a	248.60 ± 11a	247.44 ± 29a
Cold storage (5°C)													
PP	262.87 ± 21a	262.50 ± 14a	262.21 ± 10a	262.02 ± 20a	261.91 ± 22a	261.88 ± 21a	261.73 ± 14b	261.62 ± 20b	261.54 ± 21b	261.34 ± 16b	260.20 ± 13b	260.00 ± 20b	259.90 ± 12b
PP V	262.87 ± 14a	262.61 ± 10a	262.45 ± 14a	262.22 ± 26a	262.02 ± 14a	261.81 ± 24a	261.66 ± 15b	261.12 ± 15b	260.68 ± 20b	260.45 ± 21b	260.14 ± 25b	259.77 ± 26b	259.42 ± 25b
L	262.87 ± 16a	262.71 ± 11a	262.56 ± 23a	262.41 ± 25a	262.33 ± 20a	262.26 ± 15a	262.13 ± 21b	262.03 ± 14b	261.84 ± 15b	261.80 ± 25b	261.70 ± 14b	261.58 ± 22b	261.49 ± 24b
LV	262.87 ± 17a	262.80 ± 20a	262.75 ± 22a	262.69 ± 22a	262.61 ± 15a	262.56 ± 31a	262.49 ± 22b	262.36 ± 18b	262.30 ± 18b	262.24 ± 14b	262.12 ± 22b	262.08 ± 11b	262.00 ± 10b
WPP	262.87 ± 18a	261.62 ± 22a	260.45 ± 15a	259.61 ± 11a	258.44 ± 21a	257.21 ± 22a	Sp	Sp	Sp	Sp	Sp	Sp	Sp

*PP: Polypropylene; PPV: Polypropylene vacuum; L: laminated; LV: Laminated vacuum; WPP: Wooven polypropylene; J: spoiled
**Values with the same letters in a column are not significantly different at 5% level of significance.

quality parameters *viz.,* total extractable colour, oleoresin extractable colour and total carotenoid content compared to WPP bags which are due to the inherent impermeability of vacuum packaging film to oxygen and moisture. Among various treatments, vacuum packed chilli powder under cold storage showed the least per cent decline in various quality parameters. Chilli powder stored in laminated bags under vacuum (L) recorded better quality parameters over polypropylene (PP) or polypropylene under vacuum (PPV).

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