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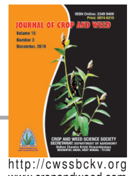

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Effect of different packaging materials on the shelf life of dried red pepper (*Capsicum annuum*. L.) stored in ambient conditions

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ABSTRACT

The investigation on shelf life of dried red pepper was conducted in ambient conditions with different packaging materials like aluminum-, LDPE- and HDPE films and paper-, gunny- and polythene lined gunny bags. A significant difference at 30- and 60-days after storage (DAS) was observed. Minimum moisture (10.67%), color values L a* b* (28.32, 36.34, 21.67), ascorbic acid (46.62 mg 100 g^{-1}), oleoresin (9.19%) with no microbial and pathogenic infestation were observed from the aluminum film at 30 DAS. At 60 DAS, the trend showed as moisture (11.23%), microbial and pathogenic infestation (0.13), colour value L*, a*, b* (25.19, 31.85, 18.85), ascorbic acid (45.05 mg100 g^{-1}) and oleoresin (8.79%) with aluminum film. However, a relatively higher moisture, microbial and pathogen infestation, lower color values, ascorbic acid and oleoresin were observed in gunny bags followed by polyethylene lined ones. So the aluminum film may be advocated as suitable packaging materials.*

Keywords: Dried red pepper, *Capsicum annuum*, aluminium film, ambient storage, ascorbic acid, HDPE film, LDPE film and oleoresin content

Chili pepper (*Capsicum annuum.* L.) is one of the most essential spices around the world irrespective of food habit. It comes under the genus *Capsicum* and the family Solanaceae. Profitable cultivation of chilli is by and large confined to tropical regions of the world, as it requires an elongated and warm period for its growth and development. They are grown for their sensorial characteristics of colour, aroma and pungency in dried form and are excellent source of nutritional phytochemicals such as ascorbic acid, carotenoids, tocopherols and phenolic compounds in green form (Nagy *et al*., 2015). A large amount of both forms of chili is gone wasted due to insufficient post-harvest management, transport, packaging and storage conveniences. The post-harvest loss of vegetables, in general, in developing countries is around 20-50% and 5-25% in developed countries. Chilli is one of the most essential vegetables as well as spices that can be spoiled in different ways needing suitable storage method to enhance the shelf life especially after drying. Shelf life is essentially the time between production and the point of degradation so far as the nutritional value, microbial status, flavor, texture and appearance of the produce is concerned. The key features of ground pepper are colour and pungency (Swain *et al*., 2013). The conventional food packaging meets the essential function of storage, preservation and safety of food (Galic´ *et al*., 2011; Kumar *et al*., 2017). To combat the external environment, packaging must be selected, designed and developed not only to hold the produce, but also to shield and include worth to it, as its design can unswervingly influence the consumer's purchasing choice. Traditionally, dried peppers are packed in jute bags. Other packing materials such as low density polyethylene (LDPE-37 µm), high density polyethylene (HDPE-75µm) and metalized polyester polyethylene (MPP-12 µm) are used to store dried chillies for prolonged period of time (Pura *et al*., 2001). In the light of the above considerations, the study has been designed to standardize dynamic wrap for extending the shelf life of dried red pepper (*Capsicum annuum*. L) stored in ambient environment.

MATERIALS AND METHODS

The research was conducted with six different packaging materials such as aluminum film, LDPE film, HDPE film, paper bags, polythene line gunny bags and gunny bags under ambient conditions with four replications in the laboratory of Department of Plantation Spices Medicinal and Aromatic crops and Quality Control Laboratory, Bidhan Chandra Krishi Viswavidhyalaya, West Bengal, India, during 2018-2019 and 2019-2020. The chilli variety (BCCH Selection 4), procured at the research field, harvested at the red ripening stage at 8 am morning hours in the month of May, was brought to the laboratory and kept in the shade for one hour to remove field heat.

Diseased and damaged peppers were removed and healthy peppers were washed in tap water to remove adhered dirt followed by drying. The red peppers were

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dried in the oven at a temperature of 65°C with a sample size of one kilogram. The research work was fitted in Randomized Complete Block Design (RCBD) with storage of two months and taking observations on different parameters as given below.

Moisture content (%)

The moisture content was determined by the technique described by as standard air oven method. The dish with dehydrated sample was transferred to a desicator and cooled to room temperature. The weight loss due to drying was used to determine the moisture content of the sample which was represented by the dry weight of the sample and denoted by percentage.

$$M.C(w.b.) = \frac{Mw}{M} \times 100$$

Mw = Mass of water, g; M = Initial mass of sample, g

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

The L*, a*, b* colour values were observed by Hunter colorimeter, (Make: Color Flex EZ spectrophotometer). Calibration of the meter was done with the manufacturer's standard white plate. Consequent changes of colour were quantified in the L*, a*, b* colour space. L*, represents lightness of the fruit sample colour ranging from black = 0 to white = 100 scale. A negative value of a* denotes a green colour, wheras, the positive value indicates red-purple colour. A positive value of b* is indicative of yellow colour and the negative value is of blue.

Ascorbic acid (mg /100g)

Ascorbic acid content of fresh and dry chilli was estimated by volumetric method describe by Sadasivam and Balasubramanian (1987).

Oleoresin (%)

Chilli oleoresin content was determined as per the method specified by Ranganna (1986).

Microbial and pathogenic infestation

Microbial and pathogenic infestation was evaluated by randomly selecting ten fruits from each treatment (different packaging materials) observed carefully and given the rating according to the intensity of infestation (1-9).

Statistical analysis

Statistical analysis of the data was done by following the procedure outlined by Panse and Sukhatme (1967). The standard error of mean and the critical difference (CD) at 5% level of significance were determined. The analyzed data have been illustrated by suitable graphs and tables.

RESULTS AND DISCUSSION

Moisture content (%)

No treatments at 0 days after storage showed significant difference among them on moisture content of the pepper. The moisture content was between 10.29 and 10.56% at 0 days after storage.

30 days after storage

In the pooled data, the highest moisture content (12.42%) was observed in gunny bag, followed by polythene line gunny bags (11.69%). However the lowest moisture content (10.67%) was recorded in the laminated aluminum film. Moisture content was significantly varied among the treatments at 30 days after storage.

60 days after storage

Moisture content varied significantly at 60 days after storage. Regarding the overall data, the maximum moisture absorption (14.60%) was shown in gunny bags and in polythene lined gunny bags (13.23%), while the minimum moisture content (11.23% and 11.51%) was found in the laminated aluminum film and LDPE film, respectively. These findings were in conformity with Al-sebaeai *et al*. (2017) who explained the minor increase in moisture content during storage mostly due to the porosity of the packaging materials and the hygroscopic nature of the chilli powder. The augmentation and reduction of moisture balance well with the relative humidity of the environment prevailing during that period. This was also established well by previous studies with paprika, where samples stored under various environments were found to be equilibrated with the ambient relative humidity (Osuna-Garcia and Wall 1998). Similar trend was obtained by Shiby *et al*. (2017) where they found that moisture gain in metalized polyester pouches was more significant than in aluminium laminated polyethylene pouches in pine apple lassi powder.

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

No treatments at 0 days after storage showed significant difference among them on colour values (L*, a*, b*).

30 days after storage

In the pooled data, the color values L*, a*, b* (28.32, 36.34 and 21.67) were shown at most in the laminated aluminum film, followed by L*, a*, b* 27.78, 35.62 and 20.99) of LDPE film and L*, a*, b* (27.05, 35.21 and 20.61) of HDPE film, while the color values L*, a*, b* (24.12, 32.24 and 18, 00) were recorded as minimum in gunny bags and significantly varied among the different storage materials at 30 days after storage.

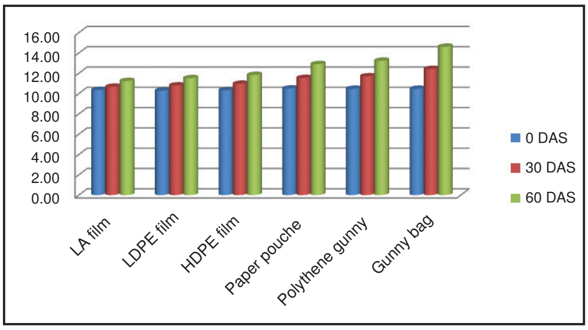

Fig. 1: Different packaging materials on moisture content (%) of dry chilli at 0, 30 and 60 days after storage

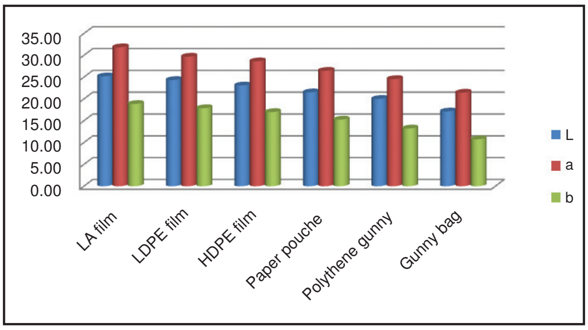

Fig. 2: Different packaging materials on colour values (L*, a*, b*) of dry chilli at 60 DAS

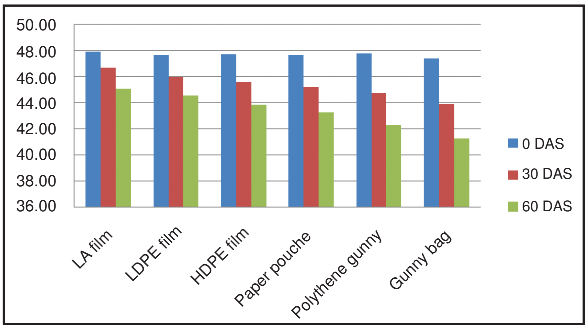

Fig. 3: Different packaging materials on ascorbic acid (mg 100 g^{-1}) of dry chilli

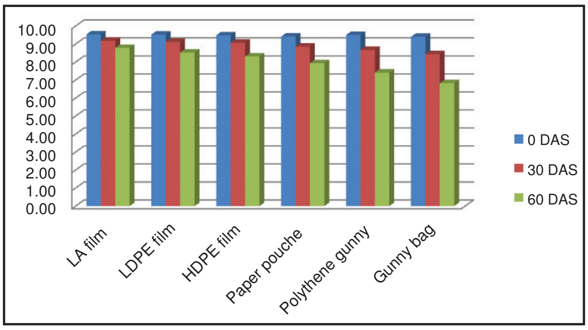

Fig. 4: Different packaging materials on oleoresin content (%) of dry chilli over time

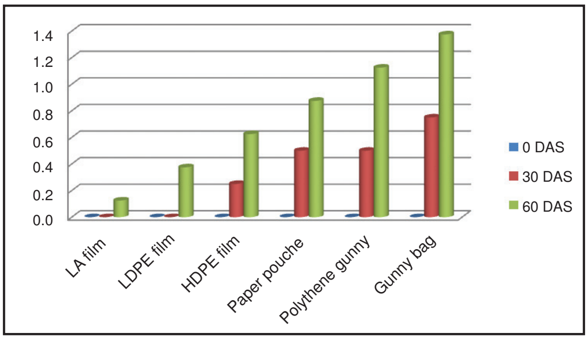

Fig. 5: Different packaging materials on microbial and pathogenic infestation of dry chilli at 0, 30 and 60 days after storage.

60 days after storage

The data on the color values of the peppers were influenced by the different storage materials and there was a significant difference between the treatments within 60 days after storage. Regarding the pooled data, it was revealed that maximum colour values L*, a*, b* (25.19,31.85 and 18.85) were shown by the laminated aluminum film, followed by the LDPE film L*, a*, b* (24.35, 29.70 and 17.90), while the minimum color values L*, a*, b* (17.14, 21.45 and 10.76) were recorded from the gunny bags. The research findings were in collaboration with Grewal *et al.* (2015). Overall, the minimum variation in colour with storage period was observed for aluminium packed samples throughout storage period. The aluminium packaging was proved best in retaining the quality of dried garlic flakes. Aluminium packaging can store safely up to 3 months than the HDPE and LDPE. Ramakrishnan and Francis (1973) also opined that the foremost change in colour of heated paprika was attributable to a large increase in brown pigments content. Park and Lee (1975) observed that brown pigment in dried red peppers was due to their elevated levels of reducing sugars and amino acids. According to Take *et al.* (2012), carotenoids are extremely stable in undamaged plant tissue. However, when processed by drying followed by grinding into powder, dry chilli may auto-oxidize simply due to the

Table 1: Different packaging materials on moisture content (%) of dry chilli over time

Treatments	0 DAS			30 DAS			60 DAS		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	10.31	10.39	10.35	10.63	10.71	10.67	11.14	11.32	11.23
LDPE Film	10.25	10.32	10.29	10.66	10.93	10.79	11.31	11.71	11.51
HDPE Film	10.29	10.32	10.31	10.66	11.26	10.96	11.51	12.16	11.84
Paper pouch	10.56	10.43	10.49	11.52	11.54	11.53	12.87	12.92	12.89
Polythene line gunny bags	10.53	10.40	10.46	11.56	11.81	11.69	12.99	13.46	13.23
Gunny bags	10.51	10.41	10.46	12.33	12.50	12.42	14.44	14.77	14.60
SEm (±)	**0.091**	**0.039**	**0.057**	**0.118**	**0.081**	**0.088**	**0.125**	**0.108**	**0.085**
LSD (0.05)	**N.S**	**N.S**	**N.S**	**0.358**	**0.248**	**0.269**	**0.38**	**0.328**	**0.258**

DAS: Days after storage, LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene

Table 2: Different packaging materials on colour values (L*, a*, b*) of dry chilli at 0 DAS

Treatments	L			A			B		
	0 DAS			0 DAS			0 DAS		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	31.85	28.84	30.35	39.27	37.11	38.19	24.66	23.26	23.97
LDPE Film	31.54	29.76	30.65	39.04	37.52	38.29	24.27	23.27	23.77
HDPE Film	31.50	29.36	30.43	39.02	37.87	38.44	24.60	22.59	23.60
Paper pouch	31.60	29.50	30.55	39.29	37.29	38.29	24.59	23.20	23.90
Polythene line gunny bags	30.95	28.60	29.78	38.77	36.94	37.85	24.82	22.71	23.77
Gunny bags	31.57	28.51	30.04	39.00	37.85	38.43	24.71	23.34	24.03
SEm (±)	**0.486**	**0.504**	**0.429**	**0.561**	**0.376**	**0.419**	**0.431**	**0.341**	**0.323**
LSD (0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

DAS: Days after storage; LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene)

Table 3: Different packaging materials on colour values (L*, a*, b*) of dry chilli at 30 DAS

Treatments	L			A			B		
				30 DAS					
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	29.58	27.07	28.32	37.03	35.66	36.34	22.05	21.29	21.67
LDPE Film	28.93	26.62	27.78	36.50	34.75	35.62	21.49	20.49	20.99
HDPE Film	28.21	25.89	27.05	36.13	34.30	35.21	21.31	19.91	20.61
Paper pouch	27.80	25.07	26.44	35.56	32.54	34.05	20.36	19.46	19.91
Polythene line gunny bags	27.04	24.76	25.90	35.03	33.46	34.24	20.02	18.40	19.21
Gunny bags	25.45	22.79	24.12	33.43	31.06	32.24	19.11	16.90	18.00
SEm (±)	**0.275**	**0.348**	**0.206**	**0.342**	**0.374**	**0.249**	**0.271**	**0.274**	**0.181**
LSD (0.05)	**0.836**	**1.059**	**0.627**	**1.039**	**1.138**	**0.757**	**0.823**	**0.833**	**0.55**

DAS: Days after storage; LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene)

Table 4: Different packaging materials on colour values (L*, a*, b*) of dry chilli at 60 DAS

Treatments	L			A			B		
	60 DAS								
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	26.04	24.33	25.19	32.82	30.89	31.85	19.18	18.53	18.85
LDPE Film	25.17	23.53	24.35	30.44	28.96	29.70	18.14	17.65	17.90
HDPE Film	24.34	21.86	23.10	29.78	27.50	28.64	17.37	16.64	17.00
Paper pouch	22.58	20.48	21.53	27.39	25.54	26.47	15.13	15.42	15.28
Polythene line gunny bags	20.72	19.33	20.03	25.78	23.36	24.57	13.14	13.34	13.24
Gunny bags	18.06	16.23	17.14	22.29	20.61	21.45	10.91	10.61	10.76
SEm (±)	**0.362**	**0.328**	**0.284**	**0.47**	**0.312**	**0.296**	**0.235**	**0.285**	**0.193**
LSD (0.05)	**1.102**	**0.998**	**0.863**	**1.43**	**0.951**	**0.899**	**0.714**	**0.868**	**0.588**

DAS: Days after storage; LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene)

Table 5: Different packaging materials on ascorbic acid (mg100 g^{-1}) of dry chilli over time

Treatments	0 DAS			30 DAS			60 DAS		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	48.25	47.50	47.88	47.04	46.20	46.62	45.80	44.30	45.05
LDPE Film	48.01	47.26	47.63	46.46	45.38	45.92	44.99	43.99	44.49
HDPE Film	47.80	47.55	47.67	46.01	45.14	45.58	44.11	43.53	43.82
Paper pouch	47.72	47.47	47.60	45.59	44.76	45.17	43.62	42.82	43.23
Polythene line gunny bags	48.21	47.21	47.71	45.24	44.34	44.71	42.95	41.60	42.27
Gunny bags	47.34	47.34	47.34	44.40	43.31	43.86	41.88	40.55	41.22
SEm (±)	**0.625**	**0.428**	**0.472**	**0.611**	**0.422**	**0.43**	**0.451**	**0.274**	**0.293**
LSD (0.05)	**N.S**	**N.S**	**N.S**	**1.840**	**1.283**	**1.307**	**1.371**	**0.834**	**0.893**

DAS: Days after storage; LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene)

Table 6: Different packaging materials on oleoresin content (%) of dry chilli over time

Treatments	0 DAS			30 DAS			60 DAS		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	9.52	9.56	9.54	9.16	9.21	9.19	8.79	8.79	8.79
LDPE Film	9.52	9.53	9.53	9.15	9.10	9.13	8.45	8.61	8.53
HDPE Film	9.44	9.54	9.49	9.14	9.00	9.08	8.26	8.36	8.31
Paper pouch	9.44	9.40	9.42	8.97	8.75	8.86	7.89	7.99	7.94
Polythene line gunny bags	9.49	9.52	9.51	8.84	8.51	8.68	7.45	7.39	7.42
Gunny bags	9.39	9.43	9.41	8.47	8.41	8.44	6.77	6.89	6.83
SEm (±)	**0.087**	**0.064**	**0.065**	**0.071**	**0.059**	**0.047**	**0.053**	**0.059**	**0.042**
LSD (0.05)	**N.S**	**N.S**	**N.S**	**0.216**	**0.178**	**0.144**	**0.16**	**0.18**	**0.128**

DAS: Days after storage; LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene)

Table 7. Different packaging materials on microbial and pathogenic infestation of dry chilli over time

Treatments	0 DAS			30 DAS			60 DAS		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
LA Film	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.13
LDPE Film	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.38
HDPE Film	0.00	0.00	0.00	0.25	0.25	0.25	0.50	0.75	0.63
Paper pouch	0.00	0.00	0.00	0.50	0.50	0.50	0.75	1.00	0.88
Polythene line gunny bags	0.00	0.00	0.00	0.50	0.50	0.50	1.00	1.25	1.13
Gunny bags	0.00	0.00	0.00	0.75	0.75	0.75	1.25	1.50	1.38
SEm (±)	**0.00**	**0.00**	**0.00**	**0.23**	**0.23**	**0.19**	**0.228**	**0.251**	**0.206**
LSD (0.05)	**0.00**	**0.00**	**0.00**	**N.S**	**N.S**	**N.S**	**0.694**	**0.765**	**0.626**

DAS: Days after storage; LA: laminated aluminum, LDPE: low density polyethylene, HDPE: high density polyethylene)

effects of heat, light and oxygen leading to a further orange and less intense tinge which degrades the value of the spice powder. The results were in close proximity with those of Hayam *et al.* (1997), Kaleemullah and Kailappan (2005), Pal *et al.* (2008), Vega-Galvez *et al.* (2008) and Mallappa *et al.* (2015) who demonstrated that the colouring matter gradually decreased as the storage period increased irrespective of the storage condition, packaging material and form of the dried product.

Ascorbic acid (mg100 g^{-1})

The ascorbic acid content has not been significantly influenced by various treatments at 0 days after storage.

30 days after storage

In the pooled data, maximum ascorbic acid (46.62 mg 100 g^{-1}) was found in the laminated aluminum film, followed by the LDPE film (45.92 mg 100 g^{-1}) and in the HDPE film (45.58 mg 100 g^{-1}). However, the minimum ascorbic acid (43.86 mg 100 g^{-1}) was found in chillies stored at gunny bags.

60 days after storage

The ascorbic acid content was statistically significant at 60 days after storage. Regarding the pooled data, the maximum ascorbic acid (45.05 mg 100 g^{-1}) was detected in the laminated aluminum film, followed by the LDPE film (44.49 mg 100 g^{-1}) and HDPE film (43.82 mg 100 g^{-1}), while minimal ascorbic acid (41.22 mg 100 g^{-1} and 42.27 mg 100 g^{-1}) was recorded in gunny bags and polythene lined gunny bags, respectively. As number of storage days increased, ascorbic acid content was decreased in all the treatments. The research results are in harmony with Al-sebaeai *et al*. (2017). The ascorbic acid content of chilli powder decreased slightly during the storage period. Similar results were obtained from Iqbal *et al*. (2015). The ascorbic acid concentration in hot peppers was reduced considerably with longer storage time. The common trend for the amount of ascorbic acid loss was alike for all samples in polyethylene bags and jute bags during storage. Garrot (1986) observed that ascorbic acid loses could be manifested due to enzymatic oxidation, thermal degradation and diffusion. Two major reasons of ascorbic acid reduction are oxidative reactions by enzymes such as cytochromeoxidase, ascorbic acid oxidase and peroxidase, aerobic and non enzymatic aerobic reactions. Daood *et al.* (1996) also reported that ascorbic acid concentration in ground paprika was decreased by 10% after 30 days followed by 20% and 35% after 60 and 120 days of storage, respectively. Our findings were in consonant with Khatun (2012) who reported that the ascorbic acid content of green chilli powder was decreased by 25% during storage and the subsequent evaluation of the effect of packaging materials showed that the samples packaged in aluminum foil retained more vitamin C and had longer shelf life in comparison to polyethylene packaging samples. Marcus *et al*. (1999) reported that the loss of ascorbic acid was retarded by the formation of caramelized products in red pepper by high temperature and long time drying.

Oleoresin content (%)

No treatments at 0 days after storage showed significant difference among them on the content of oleoresin (%).

30 days after storage

From the aggregate data, the highest oleoresin content (9.19 %) was recorded by the aluminum laminated film followed by the LDPE film (9.13%) and 9.08% by HDPE film; while the lowest oleoresin content (8.44 %) was shown in gunny bags and polythene lined gunny bags (8.68 %) at 30 days after storage. The oleoresin content varied significantly between 8.41 and 9.16 %.

60 days after storage

The oleoresin content showed significant differences among the different storage materials at 60 days after storage. In the pooled data, the oleoresin content was found maximum (8.79%) in the laminated aluminum film followed by the LDPE film (8.53%) and HDPE film (8.31%). However, the minimum oleoresin content was observed in gunny bag (6.83%) and polyethylene lined gunny bag (7.42%), respectively. All storage materials had their oleoresin content lowered as the number of days was raised. The results were in agreement with those of Gopalakrishna and Babylatha (2000) and could be ascribed to the slow decline of oleoresin components. The steady reduction rate could be endorsed to the continued oxidative deterioration of the active ingredients in chili peppers.

Microbial and pathogenic infestation

No microbial and pathogenic infestation was found in different storage materials at 0 days after storage.

30 days after storage

Microbial and pathogenic infestation was not statistically significant at 30 days after storage. In two years pooled data, the same pattern has been observed. Maximum microbial and pathogenic infestation was registered by gunny bag (0.75) followed by polythene lined gunny bags (0.50), whereas, the minimum microbial and pathogenic infestation (0.00) was observed in laminated aluminum film.

60 days after storage

Microbial and pathogen infestation differed significantly between different storage materials. Regarding the aggregated data, the microbial and pathogenic infestation (1.38) was recorded at most in the gunny bags followed by the polythene lined gunny bag (1.13), while minimal microbial and pathogenic infestation (0.13) was recorded in the laminated aluminum film at 60 days after storage. The current results were supported by Mahadevaiah *et al*. (1976). The samples stored in jute bags were infected with mold and simultaneous occurrence of typical white patches on the whole exterior together with unusual smell. This is primarily attributed to the moisture content variations in the ripe chilli fruits. However, it was found to be changed irregularly in jute bags, depending on the relative humidity of the atmosphere.

The dried peppers can be stored in suitable and appropriate packaging materials. The experimental results showed no significant difference among the treatments at 0 days after storage. A significant difference was found at 30 and 60 days after storage. The lower moisture content (11.23%), microbial and pathogen infestation (0.13), higher color values L*, a*, b* (25.19, 31.85 and 18.85), ascorbic acid (45.05mg 100 g^{-1}) and oleoresin content (8.79%) were found in the laminated aluminum film. However, high moisture content, microbial and pathogen infestation, minimal color values L*, a*, b*, ascorbic acid and oleoresin content were observed in gunny bags at 60 days after storage.

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