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Studies on Packaging of Chillies (*Capsicum annum*) in Flexible Films, and Their Laminates

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柔軟包裝材料를 利用한 고추 包裝에 關한 硏究

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SUMMARY

Studies have been carried out to design a suitable consumer size package from flexible packaging material to hold 100 grams of Chilli powder and 250 grams of whole chilli which are moisture and color sensitive.

1. Sorption characteristics of the chilli powder has revealed that moisture sorption is rapid above 55 per cent R.H., and the product is fairly hygroscopic. Further, an equilibrium moisture content of about 15 per cent at 70 per cent R.H., appears to be critical from the point of microbial spoilage of chilli powder.

2. Studies on the colour (Capsanthin) changes of chilli powder equilibriated to different moisture content, have revealed that colour changes during storage is greatly influenced by the moisture content and temperature decreases the capsanthin content of chilli during storage.

3. From the studies, it can be inferred that the sunlight exhibits pronounced effect in bleaching of colour and brings about maximum discolouration of the red pigment in chilli.

4. From the packaging and storage studies of chilli powder in different flexible films, it can be concluded that for long-term storage, the aluminium foil laminate is unique in offering maximum protection from various physico-chemical changes. For short-term storage and for fairly good moisture and colour protection, amber or black polyethylene, high-density polyethylene and Saran/Cello/Saran poly laminate pouches appear to be suitable alternatives.

INTRODUCTION

Capsicum annum Linn. and *Capsicum frutescens* Linn. are the two well recognised species. *Capsicum annum* Linn. is extensively cultivated and constitutes the principal source of dry chilli of commerce. These fruits are bringht red in colour, slender and thin walled. Colour of *Capsicum* fruits is due to caroetnoids which are susceptable to oxidative deterioration. A number of caro-

tenoids have been isolated and characterised from Capsicum[1]. The major red pigment, Capsanthin was isolated in crystalline form as early as 1927[2].

Capsicum is mainly used for its pungency, colour and contains a fair amount of vitamin C and is a rich source of vitamin A precursors. There is loss of colour during storage, and the degree of loss is influenced by storage conditions, variety of chilli, harvesting conditions and during temperature[3].

Chillies are generally marketed dry and as such, require moisture protection. In bulk, they are packed in gunny bags. Experiments have been carried out on the compressed packaging of chillies[4] as the product poses packaging problems because of its bulky nature.

Colour of chilli has been the subject of investigation [5~12] by many workers. The degradation of carotenoids contributes to the loss of attractive red colour which is influenced greatly by the moisture content, storage temperature and presence of light. To protect the product from undesirable changes, it is necessary to use protective packaging. The package, apart from having a good sales-appeal, should be functional. It must be resistant to moisture and oxygen penetration, flavour and odour contamination and must live protection against climatic hazards, microorganisms and insects.

The primary objective of this investigation was to find out a suitable flexible film or laminate in the form of pouches for packaging of chilli powder and whole-chilli in consumer unit packs of 100 grams and 250 grams respectively, and to study storage behavior of the product under different climatic conditions. The second object was to study the effect of moisture content, storage temperature and loss of red colour on exposure to sun-light.

MATERIALS and METHODS

1. Dry Chilli

Dry Chilli (Gunter variety which was bright red in colour) was obtained from the local market and was dried at 60°C for about 2 hours. One portion was powdered as such into fine particles using hammer mill and from the other lot the stalk of the chilli was removed and these two samples were used in the present investigation.

2. Packaging Materials

The pouches of the size, 11cm×13cm made of the following different packaging materials were used for packaging of chilli powder:

1. High density polyethylene of 300 gauge(H. D.P.E).
2. Low density polyethylene of 400 gauge(L. D.P.E).
3. Saran/Cello/Saran/150 gauge polyethylene. laminate.
4. Aluminium foil laminate (60 G.S.M. paper/ 0.009mm foil/150 gauge polyethylene).
5. Black polyethylene of 300 gauge.
6. Amber polyethylene of 200 gauge.
7. Unbleached kraft paper.
8. Grease-proof paper.

The pouches of the size 22cm×30cm made of the following packaging materials were used for packaging of whole-chilli:

1. High density polyethylene of 200 gauge.
2. Low density polyethylene of 200 gauge.
3. Unbleached kraft paper.

3. Analytical method

1) *Moisture determination*

Moisture was determined by drying 5~10 grams of the sample in a chamber maintained at 100~105°C for 18 hours:

2) *Capsanthin as Colour Matter*

The colour matter of the dried chilli was determined according to the method developed by Benedek[16] which is as follows:

0.25 grams of the chilli powder was accurately weighed into a conical flask and shaken with 50 ml. of pure benzene in a shaking machine for one hour. After sedimentation, 5 ml. of clear solution was pipetted out into a 50 ml. graduated flask and the solution made up to 50 ml. After shaking, the optical density of this solution was

read in "Spectronic 20" at 496nm against pure benzene as blank. From the optical density values obtained, colouring matter of the chilli is calculated with the aid of standard table and expressed as Capsanthin in grams/kg. of the material.

4. Physical properties and water vapour transmission rate (WVTR) of packaging material

In order to assess the relative merits of different packaging materials used in these investigations, their bursting, strength and tensile strength were determined by stand ASTM Methods[13]. The shelf-life of the whole chilli and chilli powder in a package is dependent on the water vapour permeability of the packaging material used. Hence, WUTR of the packaging material was determined according to I.S.I. Standard Method[14], and the result is expressed as gm/m²/24 hours under a differential gradient of 90 per cent R.H., at 38°C. The results are presented in Table I.

Table 1: Physical properties of packaging materials

Sl. No.	Packaging material	*Bursting strength (psi(kg/m²)	**Tensile strength (1b/15mm)		WVTR in gms/24 hr/m² under 90% R.H., gradient at 38°C
			M.D.	T.D.	
1.	High Density Polyethylene (300g)	25.4 (1.79)	5.48	4.86	1.88
2.	Low Density Polyethylene (400g)	21.3 (1.50)	3.7	3.15	5.54
3.	Saren/Cello/Saran/Polyethylene	38.9 (2.73)	9.5	4.96	6.66
4.	LDPE/Al. foil/Paper	21.5 (1.51)	11.5	9.26	nil
5.	LDPE 300 gauge (Black)	28.1 (1.98)	5.3	4.0	About 6
6.	LDPE (200 gauge) (Ambered coloured)	21.7 (1.53)	3.85	3.5	About 7
7.	Kraft Paper	17.5 (1.23)	6.95	5.1	Very high
8.	Grease-proof Paper	16.3 (1.15)	9.63	3.88	High (1500—2000)

*Bursting Strength in 1bs. per square inch (kg/cm²)
**MD:Machine Direction TD: Transvers Direction.

5. Sorption studies of chilli powder and whole-chilli

The chilli powder had an initial moisture content of 5.45 per cent (on dry weight basis), and the whole chilli had an initial moisture content of 7.13 per cent (on dry weight basis) as determined by drying a known weight of the product at 100 to 105°C for 18 hours in an drying chamber.

In order to study the effect of moisture on the keeping quality of the product, humidity-moisture relationship studies of the product was carried out at 27°C by placing weighed quantities of sample in petri dishes in different desiccators maintained at relative humidities ranging from 11 to 92 per cent. Saturated solutions of appropriate salts[15] were used to maintain constant humidities. The sample was periodically weighed till constant weight was obtained or till it showed signs of mold growth whichever was earlier. From the data obtained, the equilibrium moisture contents of the product at different relative humidities were calculated. The results of these studies are presented in Table 2 and graphically expressed

in Figure 1.

6. Storage studies of chilli powder, and whole-chilli with different moisture contents

Representative samples equilibrated to different moisture contents in a humidity chamber were packed in airtight glass bottles and stored at 27°C, 38°C and sun-light. The colour changes of the samples were determined by the Benedek method[16], and the results obtained are presented in Tables 6~8.

7. Storage studies

Storage studies of chilli powder were carried out in small pouches of size 11cm×13cm containing 100grams of chilli powder; while that of whole-chilli were carried out in bag of size 32cm ×30cm containing 250 grams of dried pods.

The pouches were made from different flexible films and their laminates described earlier, and each pouch was filled with product and was then closed by heat-sealing.

The packages were then exposed to the following conditions of storage: (1) 27°C and 65 per cent (plus or minus 2 per cent R.H.) under the I.S.I., Standard Test Condition, (2) at 38°C and 92 per cent (plus or minus 2 per cent) under accelerated conditions of storage, (3) exposed to sun-light for 5-6 hours per day under varying climatic conditions.

The samples kept in air-tight glass bottles under the above conditions of storage served as control.

The packets were periodically weighed and were drawn at different intervals of time and analysed for their moisture and Capsanthin contents. The results are presented in Table 3~10.

RESULTS AND DISCUSSION

1. Sorption characteristics

Equilibrium relative humidity studies at 27°C have indicated that the chilli powder is fairly hygroscopic and with an initial moisture content of 5.45 per cent would equilibrate to an R. H. of about 20 per cent. The sorption isotherm (Fig. 1) is of typical sigmoid type and shows a steep

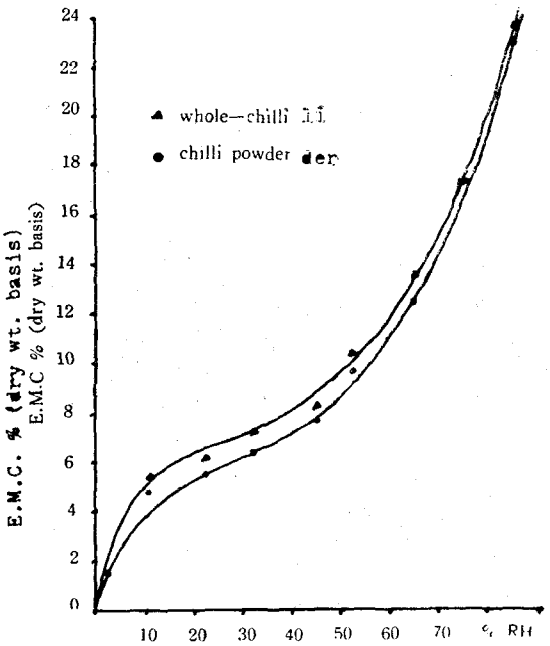

Fig. 1. Sorption isotherm of chilli at 27C

rise above 55 per cent R.H. Generally, it is recognised that the onset of the rapid raise (rapid increase in moisture content) in the sorption isotherm is an indication of beginning of fast chemical and physical deterioration of the product. On this basis, the equilibrium moisture content of about 10 per cent at 50 per cent R.H., could be considered as safe moisture content of the product. Above an R.H. of 55 per cent, there was sharp increase in sorption and at 75 per cent R.H., with a moisture content of 17.5 per cent, the product developed mold growth. At 86 per cent and 92 per cent R.H., the product equilibrated to high moisture levels and developed mold growth within few days. At 64 per cent R.H., chilli powder with an EMC of 12.5 percent was quite acceptable. It is observed that processed foods in general are susceptible to fungal spoilage at 70 per cent R.H., and above[17] Based on this observation and extropalation from the Fig. 1, an EMC of 15 per cent at 70 per cent R.H., appears to be critical from the point of microbial spoilage of chilli powder.

The sorption results of whole chilli (without

stalk) is similar to one of chilli powder. Eventhough there is about 0.5~1% divergence in EMC at intermediate humidities, the sorption isotherm of whole-chilli converges at higher humidities. The ERH of whole chilli with 7.13 per cent moisture content is about 30 per cent and at 70 per cent R.H., it has an EMC of 15.5 per dent.

2. Colour changes in chillies with different moisture contents

Change in the Capsanthin content (colour) of the chilli powder and whole-chilli with different moisture contents, and stored for 20 days at different conditions is presented in Table 2. It can be seen from the Table 2 that at the end of

Table 2. Colour changes in chilli powder and whole-chilli in the glass bottles stored at different climatic conditions.

Initial colour: 2.64 gm/kg.
Storage period: 90 days.

Colour value in controlled store: 0°C=2.43.

Conditions of storoge	Chilli powder				Whole chilli		
	Moisture content (%)				Moisture content (%)		
	4.51	8.02	11.47	15.06	6.08	9.15	12.53
Stored at ISI condition at 27°C and 65% R.H.	2.34	2.07	1.76	1.72	2.22	2.02	1.98
Stored at 38°C and 92% R.H.	2.23	2.01	1.85	1.81	1.80	1.71	1.64
Exposed to Sun-light for 6 hours/day.	1.73	1.60	1.45	1.43	1.41	1.38	1.34

90 days storage under different conditions, the colour in chillies decreases with increase in moisture content. From the results, it is evident that the colour of chilli powder with 8 per cent moisture is less than the one with 4.5 per cent moisture. At higher levels of moisture, there is further decrease in colour under all conditions of storage.

The above results are conflicting to the observation of Chen and Gtmanis[5], Whose studies have indicated that at higher moisture levels (0~10 per cent), the extractable colour was more as compared to samples stored at lower moisture level (less than 7 per cent). This difference in results is perhaps due to the extraction procedures followed. The above authors have used acetone extraction and in the present study, extraction by benzene is used and total colour is expressed as grams of Capsanthin in kilogram of the material. Thus, it is probable that the Capsanthin degradation is linear and decrease with increase in moisture content.

The samples with moisture contents higher than 8 per cent grew darker (especially whole chilli), and showed further decrease in colour and was lowest in the sample having 15 per cent moisture.

It can be seen from the Table 2 that at all moisture levels, the colour of the sample decrease with increase in the temperature of the storage. Further, comparison of results indicate that there is pronounced bleaching of colour (at all moisture levels) in the samples stored in sun-light. This bleaching was quite marked in white. This bleachingwas quite marked in whole-chilli where in many chilli pods had turned complete white. This observation of pronounced bleaching in sun-light is in agreement with the results of Rosalite de La Mar *et al*[10]. Who have observed that sun-light bleaching results in loss of nearly 96 per cent in total extractable pigment expressed as β-carotene.

From the colour (Capsanthin) changes observed in the above set of experiments, it can be concluded that the loss of Capsanthin in chilli powder during storage is greatly influenced by the moisture content and temperature. Further, sun-light exhibits a pronounced effect in the bleaching process and brings about maximum

discolouration of red pigment in chilli.

3. Storage studies in flexible films and laminates

1) *Changes in mosture*:

It can be seen from the Tables 3, 4 and 5 that at the end of 90 days storage at 38°C and 92 per cent R. H,. (Table 4), the moisture content of chilli powder in aluminium foil laminate is 5.54 per cent as against the initial value of 5.45 per cent. in comparison, the moisture content of the chilli powder ranges from 9 to 13 per cent in other packaging materials during the same period of storage. Samples in kraft and grease-proof paper pouches developed mold growth 25 days. The moisture pick-up in different packaging materials under the storage condition of 27°C and 65 per cent R.H., (vide Table 3). indicate a similar trend of results even at 92 per cent R.H., at 38°C. In the samples stored in the open atmosphere under sun-light, it can be seen from the Table 5 that there is not much change in moisture in different packages. However, there has been pronounced bleaching in colour in all the above packages.

The water vapour transmission rates of the packaging materials reported in Table 10 explain to a fair degree of the trend in moisture pick-up by the chilli powder in different pouches. From the results, it can be concluded that aluminium foil laminate pouch offers maximum shelf-life

Table 3. Percentage moisture content of chilli powder in packets stored at 27°C and 65% R.H. (M.C. on packet basis)

Initial M.C.: 5.45 Per cent.

Sl. No.	Packaging materials	Storage period in days				
		20	35	50	70	90
1.	H.D.P.E.	5.66	5.82	5.96	6.17	6.45
2.	L.D.P.E.	5.64	6.06	6.25	6.57	6.78
3.	Saran/Cello/Saran/PE	5.78	6.21	6.58	6.95	7.18
4.	Aluminium foil laminate	5.49	5.50	5.51	5.53	5.55
5.	Kraft Paper	10.98	11.52	11.87	12.32	13.92
6.	Grease-proof Paper	9.37	10.66	11.83	12.24	13.69

Table 4: Percentage moisture content of chilli powder in packets stored at 38°C and 92% R.H., (M.C. on packet basis)

Initial moisture content: 5.45 per cent.

Sl. No.	Packaging materials	Storage period in days				
		20	35	50	70	90
1.	H.D.P.E.	6.59	7.01	7.66	8.40	9.04
2.	L.D.P.E.	7.28	8.24	9.22	10.21	11.10
3.	Saran/Cello/Saran/P.E.	8.14	9.31	10.52	12.20	13.12
4.	Aluminium foil Laminate	5.49	5.50	5.51	5.52	5.54
5.	Black PE	7.08	7.94	8.35	10.07	11.65
6.	Amber PE	7.60	8.05	8.21	10.50	12.67
7.	Kraft paper	11.87	mould growth (Heavy)	—	—	—
8.	Grease-proof Paper	12.90	Heavy mould growth	—	—	—

Table 5: Percentage moisture content of chilli powder in packets exposed to sun-light for 6 hours for a day. (M.C. on packet basis)

Initial M.C.=5.45 per cent.

Sl. No.	Packaging material	Storage period in days				
		20	35	50	70	90
1.	H.C.P.E.	5.54	5.71	5.81	5.92	6.14
2.	L.D.P.E.	5.52	5.53	5.70	5.93	6.18
3.	Saran/Cellu/Saran/PE	5.43	5.31	5.60	6.60	6.67
4.	Aluminium foil Laminate	5.49	5.50	5.51	5.52	5.54
5.	Black PE	5.48	5.54	5.62	5.82	5.96
6.	Amber PE	5.56	5.67	5.88	6.36	6.84
7.	Kraft paper	5.51	5.55	6.67	7.05	7.45
8.	Grease-proof paper	5.64	5.97	6.21	7.69	8.66

for the product. However, for a product of this type, aluminium foil laminate will be costlier. As the product with even 13~14 per cent of moisture content is quite safe microbiologically, it can be inferred that high density and low density polyethylene film pouches are also quite suitable.

2) *Colour changes in different packages*:

Changes in colour of chilli powder at different conditions of storage in various packages are reported in Tables 6, 7 and 8. The chilli powder had an initial colour value (expressed as Capsanthin) of 2,64 gm/kg. of the sample and this value decreased in all pouches at all conditions of storage. The decrease at the end of 90 days storage was most pronounced in samples exposed to sun-light. In all packages, the loss in colour at 92 per cent R.H. and 38°C was more than at 27°C and 65 per cent R.H.

Of the different materials used, aluminium foil laminate pouch was unique in keeping the colour of chilli powder under various conditions of storage. This laminate with its outstanding barrier properties for gas and water vapour and with opacity to light, will give a good shelf-life for the product. Daeud and Lulla[11] have observed that a laminate of the above type is quite effective in protecting freeze-dried red-bell peppers from moisture, oxygen and light. lowever, because of its high cost, its use for comparatively low-cost product like chilli powder has to be reconsidered. From the data on the moisture content and colour changes of chilli powder in amber and black polyethylene and high density polyethylene (vide

Table 6: Colour changes in chilli powder in packets stored at 27°C and 65% relative humidity (Quantity of Capsanthin: g/kg)

Initial weight: 2.64gms.

Sl. No.	Packaging material	Storage period in days					
		15	30	45	60	75	90
1.	H.D.P.E.	2.51	2.43	2.33	2.23	2.21	2.12
2.	L.D.P.E.	2.45	2.25	2.13	2.01	1.86	1.55
3.	Saran/Cello/Saran/PE	2.53	2.43	2.25	2.23	2.16	2.12
4.	Aluminium foil laminate	2.48	2.43	2.34	2.28	2.23	2.12
5.	Kraft Paper	2.12	1.94	1.78	1.65	1.52	1.43
6.	Grease-proof paper	2.20	2.08	1.95	1.81	1.72	1.62

Table 7: Colour changes in chilli powder in packets stored at 38°C and 92% relative humidity (quantity of Capsanthin: g/kg)

Initial weight: 2.64 g/kg.

Sl. No.	Packaging material	Storage period in days					
		15	30	45	60	75	90
1.	H.D.P.E.	2.23	2.10	1.81	1.69	1.42	1.08
2.	L.D.P.E.	2.25	1.92	1.86	1.60	1.48	1.24
3.	Saran/Cello/Saran/P.E.	2.35	2.17	2.12	1.71	1.51	1.08
4.	Aluminium foil laminate	2.41	2.33	2.05	1.90	1.81	1.69
5.	Black PE	2.35	2.23	1.96	1.74	1.65	1.24
6.	Amber PE	2.24	2.07	1.85	1.64	1.50	1.24
7.	Kraft Paper	1.81	1.34	—	—	—	—
8.	Grease-proof Paper	2.12	1.50	—	—	—	—

Table 8: Color changes in chilli powder in packets exposed to sun-light (6 hours per day) (Quantity of Capsanthin: g/kg).

Initial weight: 2.64g/kg.

Sl. No.	Packaging material	Storage period in days					
		15	30	45	60	75	90
1.	H.D.P.E.	2.17	1.76	1.29	1.18	1.01	0.82
2.	L.D.P.E.	1.92	1.79	1.65	1.28	1.19	0.98
3.	Saran/Cello/Saran/PE	2.14	2.02	1.81	1.65	1.55	1.08
4.	Aluminium foil laminate	2.45	2.38	2.23	2.15	1.93	1.68
5.	Black PE	2.23	2.07	1.54	1.50	1.38	1.13
6.	Amber PE	2.22	2.05	1.90	1.61	1.45	1.16
7.	Kraft paper	2.23	2.02	1.92	1.88	1.44	1.31
8.	Grease-proof paper	2.08	1.76	1.60	1.49	1.28	1.07

Tables 3 to 8), it appears that they are quite suitable for short-term storage of three months even under accelerated condition of storage (92 per cent R.H., and 38°C). Saran/Cello/Saran-Polyethylene laminate appears to be quite good under storage condition of 27°C and 65 per cent R.H. However, it was observed that under drastic conditions of sun-light, this packaging material gets desiccated and the pouch gives away at seals and looses its good barrier properties. Under normal conditions, this laminate exhibits a better performance than low-density polyethylene film pouch.

From the packaging and storage studies of chilli powder in different films, it can be concluded that for longterm storage, the aluminium foil laminate is unique in offering maximum protection from various physico-chemical changes. For short-term storage and for fairly good moisture and colour protection, amber or black coloured polyethlene, high-density polyethylene and Saran/Cello/Saran polyethene laminate appear to be suitable alternatives.

4. Storage studies of whole-chilli

Moisture and colour changes in whole-chilli at the end of 90 days storage under different conditions in polyethylene and kraft paper bags are presented in Table 9.

The trend in results were quite similar to one of the chilli powders. The sample exposed to

Table 9: Changes in moisture and colour in whole-chilli after 90 days storage.

Initial moisture content: 7.13 per cent. Initial colour: 2.64 gm/kg

Sl. No.	Packaging material	Stored at 27°C and 65% R.H.		Stored at 38°C and 92% R.H.		Exposed to sun-light for 6 hours per day	
		% moisture content	Quantity of Capsanthin (g/kg)	% moisture content	Quantity of Capsanthin (g/kg)	% moisture content	Quantity of Capsanthin (g/kg)
1.	High Density Polyethylene	8.10	1.65	9.96	1.65	4.93	1.29
2.	Low Density Polyethylene	7.21	1.71	8.38	1.76	4.96	1.35
3.	Kraft Paper	10.21	2.16	13.21	1.19	7.01	1.14

sun-light had bleached and had very dull appearance in all the three packaging materials. The sample stored at 92 per cent R.H., and at 38°C in HDPE, LDPE and kraft had turned dark and had dull appearance. At 27°C and 62 per cent R.H., eventhough there was slight loss in colour, the chilli pods had retained quite bright colour. From the results, it can be said that kraft paper under temperate conditions 200 gauge, low density polyethene under tropical conditions are suitable for packaging of whole-chilli in consumer unit container of 250 grams.

要 約

現在 食品工業에 널리 利用되고 있는 包裝材料를 가지고 乾燥통고추와 고추粉末을 包裝하여 여러 條件에 貯藏하면서 包裝材料와 試料의 物理的 및 化學的 變化에 關하여 硏究檢討 한바 다음과 같은 結果를 얻었다.

고추의 貯藏條件中, 相對濕度 55% 以上에서는 水分吸收가 顯著하게 上昇하였으며, 70%에서는 곰팡이가 發生하였는데 이때의 平衡水分 含量은 15%로써 고추의 貯藏水分 含量의 臨界點에 到達하였다. 試料의 水分含量을 달리하여 貯藏하였을 때 色素 Capsanthin含量은 貯藏溫度가 높을수록, 水分含量이 많아질수록 減少하였으며, 天日下에 放置할때도 Capsanthin含量은 크게 變化하였다. 여러 包裝材料中 Aluminium foil packet이 長期貯藏時 고추 成分의 變化를 줄이는데 가장 效果的이였으며 短期貯藏時에는 着色 Polyethylene, L.D.P.E., Saran/Cello, /Saran/P.E., 順序였다.

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