

**EFFECT OF DIFFERENT PACKAGES ON THE STORAGE ABILITY OF
BROCCOLI SPEARS**

BY

Abo El-Hamd, A.S.A. and Esmail, A.A.M.
Department of Horticulture, Faculty of Agriculture Al- Azhar University

ABSTRACT

The work had involved studies on the cultivar "De Cicco" of broccoli to test the effect of different packages on the storage ability of broccoli spears. Spears of 20 days age were stored under cold storage at 5°C and 90-95% R.H. in board carton boxes of different sizes (30 x 20 x 10, 40 x 30 x 9 and 45 x 30 x 14cm) and/or non-perforated and vented polyethylene bages (45 x 30cm) with ventilation holes of 0.15, 0.30 and 0.45%. Unpacked spears were considered as control spears. The big board carton boxes proved to be most effective one in minimizing the loss in weight percentage than the other two sizes. Non-perforated ones were used for reducing the loss in weight percentage. No materially differences existed in the spears unmarketable percentage due to the application of the various board carton boxes. The spear contents of T.S.S., ascorbic acid, total chlorophyll and total sugars were higher when stored in the big board carton boxes than those ones stored in the other two sizes. The non-perforated polyethylene bags were the most obvious bags in modifying storage as it was characterized with the highest percent of CO₂ and the lowest of O₂.

INTRODUCTION

The successful marketability of broccoli spears packages on maintaining high quality after harvesting and the application of the packages. The use of fiberboard carton boxes revealed that the small size of 4kg. surpassed those of 6 or 10kg. in minimizing the loss in weight percentage in tomato (Abo-El-Hamd, 1981).

In seeking to follow the packing of broccoli by polymeric films, it had been shown that this film retard the decay of the stored material (Shewfelt *et al.* 1983)

Storing tomato fruits in perforated polyethylene bags showed that fruit T.S.S. content were higher during storage than those of the control ones (Hassan *et al.* 1970)

Some experiments were carried out on storing broccoli in bags to determine the effect of elevated CO₂ concentrations on spear ascorbic acid content

It is clear that, CO₂ reduced the level of ascorbic acid loss in the packaged spears than the non-packaged ones (Wang, 1979).

Storing broccoli spears in polyethylene bags proved that the modified atmosphere inside these bags retained more chlorophyll content during storage than the non packed once (Zhuang *et al.*, 1994).

To examine the effect of polyethylene bags on the concentrations of fruit sugars during storage, it was noticed from one of the experiments done on broccoli that packing of spears in these bags kept more higher content of sugars than the unpacked ones (Yamashita *et al.*, 1993).

MATERIALS AND METHODS

The variety "De Cicco" of broccoli (*Brassica oleracea L., var. italica Plenck*) was used in this investigation. Two trials were conducted in a private farm at Miniut ElSebaa near Banha, Kalubia Governorate during the two successive winter season of 1993-1994 and 1994-1995, to study the effect of some post-harvest packages treatments. The soil type of this area is silt-loam.

Spears of 20 days age were stored under cold conditions at the temperature of 5°C and R.H. of 90-95% as recommended before by Forney and Rig. (1991). The following packages were examined:

1. **Cardboard carton boxes:** Three different sizes of boxes were evaluated. They were 30x20x10cm, 40x30x9cm and 45x30x14cm.
2. **Polyethylene:** Two types of these bags of the same size 45x30cm were checked, the non-perforated and the vented ones. The vented polyethylene bags had ventilation holes of 0.15, 0.30 and 0.45%. However, unwrapped spears represented the control ones.

All the cold stored broccoli spears in the different packages were represented in three replicates and devoted to the physical and chemical analysis every 7 days during the whole storage periods. The examined characteristics were:

- a- **Physical changes:** Loss in weight percentage, and unmarketable percentage.
- b- **Chemical changes:** Total soluble solids, ascorbic acid, total chlorophyll, total sugars, and carbon dioxide and oxygen.

The determination of the changes in the concentrations of CO₂ or O₂ during storage was done within the different perforated or non-perforated polyethylene bags in the second season only.

Determination procedures:

a- Physical characteristics:

- 1- **Loss in weight percentage:** The percentage of loss in weight was calculated as follows:

$$\text{Loss in weight \%} = \frac{\text{Loss in weight at the sampling date}}{\text{The initial weight of spears}} \times 100$$

- 2- **Unmarketable percentage:** The percentage of unmarketable spears was determined according to the following equation:

$$\text{Unmarketable spears \%} = \frac{\text{Total number of unmarketable spears at the sampling date}}{\text{The initial number of spears}} \times 100$$

b) Chemical characteristics:

- 1- Total soluble solids percentage was determined by Abbe refractometer (A.O.A.C., 1980).
- 2- Ascorbic acid content was determined by using the dye 2,6 dichlorophenolindophenol method (A.O.A.C., 1980). The results were calculated as mg./100g. fresh weight
- 3- Total chlorophylls concentration was determined as mg./100g. fresh weight according to Robbelen method (1957).
- 4- Total sugars were determined adopting the colorimetric method for the determination of sugars and related substances according to Dubois *et al.*, (1956). The results were calculated as g./100g. dry weight.
- 5- CO₂ and O₂ determinations were carried to follow the changes in the concentrations of CO₂ and O₂ inside the packages during the storage of spears by using Gas chromatography (Carl special series-S model AGC III). Gas samples (1 ml) were taken by syringe from the top of the package film and injected into injector. The concentrations of CO₂ and O₂ were determined according to Cross (1966) as follows:

Concentration of CO₂ and O₂ for sample =

$$\frac{\text{Peak height for sample}}{\text{Peak height for standard gas}} \times \text{concentration of standard gas\%}$$

RESULTS AND DISCUSSION

a- Physical changes:

Presented data in Table (1) show the effect of different types of packages on the spear loss in weight percentage during the various storage periods in the two seasons of 1993-1994 and 1994-1995. The expected gradual increase in this criterion took place with the advance of storage periods. However, the big size package (45x30x14cm) proved to be the most effective one in reducing the losses after 7 days of storage when compared with the medium (40x30x9cm) and small (30x20x10cm) ones. On the other hand, the non-perforated polyethylene bags surpassed all the other types of bags in minimizing this loss. On the whole, the non-perforated polyethylene bags were the most obvious ones in reducing this character over all the used packages. These study agreement with (Abo-El-Hamd, 1981) on tomato.

Data on the effect of different examined packages on the unmarketable percentage of spears during storage in 1993-1994 and 1994-1995 seasons are shown in Table (2). The general view reflect that this deterioration increased gradually with the extend of the storage periods. Evidences from the results show that similar figures of the unmarketable spears were obtained from using all the fiberboard carton bags. Concerning the polyethylene bags, it is clear that the non-perforated ones were the most effective ones in minimizing the unmarketable percentage in the whole storage periods. These is agreement with (Shewfelt *et al.*, 1983) on broccoli spears.

Table (1): Effect of different packages on spear loss in weight percentage during cold storage.

Treatments	Storage periods (in days)					
	7	14	21	28	35	42
1993-1994						
Fiber board carton box						
30 x 20 x 10 cm	2.20	6.40	9.35	12.50	-	-
40 x 30 x 9 cm	2.20	5.70	7.70	9.70	-	-
45 x 30 x 14 cm	2.60	4.30	6.90	7.70	-	-
Perforated polyethylene bags						
0.15 %	0.52	1.05	1.30	1.91	2.48	-
0.30 %	0.92	1.90	2.25	2.70	-	-
0.45 %	1.32	2.66	3.30	3.90	-	-
Non-perforated polyethylene bags	0.38	0.68	0.82	1.22	1.45	1.68
Control	3.81	9.60	14.20	-	-	-
1994-1995						
Fiber board carton box						
30 x 20 x 10 cm	2.10	6.10	8.90	12.10	-	-
40 x 30 x 9 cm	2.08	5.10	6.90	9.30	-	-
45 x 30 x 14 cm	2.20	4.07	6.20	7.10	-	-
Perforated polyethylene bags						
0.15 %	0.65	1.15	1.90	2.20	2.90	-
0.30 %	1.13	2.15	2.95	3.70	-	-
0.45 %	1.40	3.20	3.99	4.96	-	-
Non-perforated polyethylene bags	0.38	0.79	1.12	1.75	1.95	2.35
Control	4.20	9.90	15.20	-	-	-

Table (2): Effect of different packages on spear unmarketable percentage during cold storage.

Treatments	Storage periods (in days)						
	Treatments						
	Storage periods (in days)						
	7	14	21	28	35	42	49
1993-1994 seasons							
Fiber board carton box							
30 x 20 x 10 cm	0	0	20	50	100	-	-
40 x 30 x 9 cm	0	0	20	50	100	-	-
45 x 30 x 14 cm	0	0	0	50	100	-	-
Perforated polyethylene bags							
0.15 %	0	0	0	20	50	100	-
0.30 %	0	0	0	50	100	-	-
0.45 %	0	0	0	50	100	-	-
Non-perforated polyethylene bags	0	0	0	0	10	20	100
Control	0	0	80	100	-	-	-
1994-1995 seasons							
Fiber board carton box							
30 x 20 x 10 cm	0	0	20	50	100	-	-
40 x 30 x 9 cm	0	0	20	50	100	-	-
45 x 30 x 14 cm	0	0	0	50	100	-	-
Perforated polyethylene bags							
0.15 %	0	0	0	20	50	100	-
0.30 %	0	0	0	50	100	-	-
0.45 %	0	0	0	50	100	-	-
Non-perforated polyethylene bags	0	0	0	0	10	20	100
Control	0	0	80	100	-	-	-

b- Chemical changes:

The results in Table (3) indicate that the spear T.S.S. content in all the packages were reduced with the extend of the storage periods in the two seasons of 1993-1994 and 1994-1995. Comparing the various treatments of Fiber-board carton boxes, it is clear that the biggest box (45 x 30 x 14 cm) kept the highest concentration of T.S.S. compared with the other boxes and similarly the non-perforated polyethylene bags over the various examined bags. However, the last mentioned bags remained of the biggest concentrations of T.S.S. in respect with the other packages. This is agreement with (Hassan *et al.*, 1970) on tomato fruits.

The effect of the different packages on the spear ascorbic acid content during storage in 1993-1994 and 1994-1995 seasons is represented in Table (4). All the used packages exhibited a general trend of decrease in this content during storage. The picture reflects that the amount of ascorbic acid content in spear

stored in the biggest fiberboard carton boxes (45 x 30 x 14 cm) was higher than those of the medium (40 x 30 x 9 cm) or the small (30 x 20 x 10 cm) ones. On the other hand, using the non-perforated polyethylene bags kept the highest vitamin content during storage compared with the other examined bags. In the same time, these bags, i.e. the non-perforated ones, were more higher in ascorbic acid than all the tested boxes during storage.

Table (3): Effect of different packages on spear total soluble solids percentage during cold storage.

Treatments	Storage periods (in days)						
	0	7	14	21	28	35	42
1993-1994							
Fiber board carton box							
30 x 20 x 10 cm	10.20	7.80	6.50	5.20	4.10	-	-
40 x 30 x 9 cm	10.20	7.90	6.70	5.50	4.30	-	-
45 x 30 x 14 cm	10.20	8.10	6.90	5.80	4.60	-	-
Perforated polyethylene bags							
0.15 %	10.20	8.80	7.70	6.30	5.10	-	-
0.30 %	10.20	8.40	7.40	6.10	4.90	-	-
0.45 %	10.20	8.20	7.20	5.70	4.50	-	-
Non-perforated polyethylene bags	10.20	8.60	7.80	6.50	5.30	4.60	3.90
Control	10.20	7.40	4.30	3.00	-	-	-
1994-1995							
Fiber board carton box							
30 x 20 x 10 cm	10.50	8.10	6.80	5.50	4.00	-	-
40 x 30 x 9 cm	10.50	8.20	6.90	5.90	4.40	-	-
45 x 30 x 14 cm	10.50	8.60	7.20	6.10	4.50	-	-
Perforated polyethylene bags							
0.15 %	10.50	9.00	8.00	6.70	5.20	4.20	-
0.30 %	10.50	8.60	7.80	6.50	5.00	-	-
0.45 %	10.50	8.30	7.60	6.20	4.70	-	-
Non-perforated polyethylene bags	10.50	9.20	8.20	7.00	5.60	4.80	3.80
Control	10.50	7.80	4.50	3.00	-	-	-

The data presented in Table (5) about the effect of different packages on the spear chlorophyll content during storage in the two seasons of 1993-1994 and 1994-1995 show that the values in all the tested packages diminished gradually with the elapse of the storage periods. This disappearance of the green colour was not the same in the examined packages. However, the biggest fiberboard carton box (45 x 30 x 14cm) was the leader in keeping comparatively the highest chlorophyll concentrations during storage than the other boxes. From another point of view, good results were obtained from those spears stored in the non-perforated polyethylene bags as it maintained comparatively to the other bags the

highest chlorophyll concentrations. However, the non-perforated polyethylene have were the best packages in keeping chlorophyll concentrations during storage compared with all the other tested packages. This is a study agreement with (Ahuang *et al.*, 1994) on broccoli

Table (4): Effect of different packages oil spear ascorbic acid (mg/100 g.f.w.) during cold storage.

Treatments	Storage periods (in days)						
	0	7	14	21	28	35	42
1993-1994							
Fiber board carton box							
30 x 20 x 10 cm	105	83.40	72.10	61.70	51.30	-	-
40 x 30 x 9 cm	105	84.20	73.00	62.40	52.20	-	-
45 x 30 x 14 cm	105	84.90	73.90	62.80	52.90	-	-
Perforated polyethylene bags							
0.15 %	105	90.99	77.60	65.40	55.20	43.50	-
0.30 %	105	89.10	76.50	64.20	54.30	-	-
0.45 %	105	85.20	74.20	63.10	52.90	-	-
Non-perforated polyethylene bags	105	92.60	79.40	67.30	57.10	44.60	30.80
Control	105	75.30	61.90	45.30	-	-	-
1994-1995							
Fiber board carton box							
30 x 20 x 10 cm		90.60	79.30	67.50	55.60	-	-
40 x 30 x 9 cm	112.6	91.40	80.50	68.60	56.80	-	-
45 x 30 x 14 cm	112.6	91.80	81.10	69.10	57.20	-	-
Perforated polyethylene bags							
0.15 %	112.6	98.20	87.40	72.30	60.10	50.80	-
0.30 %	112.6	97.30	86.20	71.70	59.20	-	-
0.45 %	112.6	93.60	84.30	70.20	58.00	-	-
Non-perforated polyethylene bags	112.6	100.1	89.20	75.30	66.10	54.30	41.30
Control	112.6	81.80	65.40	50.10	-	-	-

The results in Table (6) show the effect of various packages on the spear total sugars during the storage periods in the two seasons of 1993-1994 and 1994-1995. It is clear that there was a decline trend in total sugars in all the stored spears during the various storage periods. However, the biggest fiberboard carton boxes (45x30x14cm) kept more sugars than the other boxes all over the storage periods. On the other hand, spears packed in non- perforated polyethylene bags hold more total sugars during storage than those kept in the other different bags. Specifically speaking, the non-perforated polyethylene bags were the most obvious one in reversing total sugars in comparison with the other packages. This is agreement with (Yamashita *et al.*, 1993) on broccoli spears.

Table (5): Effect of different packages on spear total chlorophyll (mg/100 g.f.w.) during cold storage.

Treatments	Storage periods (in days)						
	0	7	14	21	28	35	42
1993-1994							
Fiber board carton box							
30 x 20 x 10 cm	52.80	44.10	37.20	30.20	16.60	-	-
40 x 30 x 9 cm	52.80	54.20	38.50	31.40	16.90	-	-
45 x 30 x 14 cm	52.80	46.40	39.80	31.90	17.30	-	-
Perforated polyethylene bags							
0.15 %	52.80	46.30	43.50	39.30	33.10	25.30	-
0.30 %	52.80	45.10	40.00	37.10	30.20	-	-
0.45 %	52.80	44.00	39.20	31.40	28.10	-	-
Non-perforated polyethylene bags	52.80	49.80	47.70	43.60	40.50	38.60	35.10
Control	52.80	30.40	21.20	12.80	-	-	-
1994-1995							
Fiber board carton box							
30 x 20 x 10 cm	55.00	47.20	39.20	33.10	22.10		
40 x 30 x 9 cm	55.00	48.40	40.60	34.60	23.10		
45 x 30 x 14 cm	55.00	49.60	40.90	35.80	24.80		
Perforated polyethylene bags							
0.15 %	55.00	50.90	46.10	42.80	35.60	25.20	-
0.30 %	55.00	49.20	44.20	40.30	34.10	-	-
0.45 %	55.00	47.30	40.10	37.70	32.00	-	-
Non-perforated polyethylene bags	55.00	52.80	50.50	48.10	45.20	40.90	37.30
Control	55.00	33.10	24.90	15.20	-	-	-

The figures of O₂ and CO₂ represented in table (7) show the effect of the various polyethylene bags on the changes happened in the levels of both gases inside the bags during storage in 1994-1995 season. It is clear as a general trend that while the levels of oxygen decreased those of carbon dioxide increased in all the non-perforated and perforated polyethylene bags during the whole storage periods. Comparing the various treatments, it is easy to notice that the modified atmosphere was more higher in the non-perforated polyethylene bags than the perforated ones. However, the lesser the perforation percentages the more the control atmosphere (CO₂) be. In other words, the perforated bags of 0.15 % was the most favorable one regarding this item than 30 and 45 % ones.

It is evident from the results of packaging that there was an increase trend in the loss in weight with every extend of the storage periods. However, the continuous loss in weight during storage may be attributed to both loss of humidity through transpiration and dry matter by respiration as mentioned before in the storage of the spear development ages. The big boxes (45 x 30 x 14cm) and

the non-perforated polyethylene bags surpassed all the other types of boxes or bags in minimizing this loss with the priority of the non-perforated polyethylene bags. However, the desirable effect of the non-perforated polyethylene bags in reducing the weight loss may be due to the role of these bags in hindering the water loss from the spears which in turn reduced this percentage (Rij and Ross, 1987). Hence, these results are in harmony with those obtained in broccoli spears when it was found that the weight loss during storage was less by 50% in wrapped non-perforated flexible polyvinylchloride (PVC) film comparatively to the control ones (Forney *et al.*, 1989). This study agreement with (Abo El-Hamd; 1981) on tomato.

Table (6): Effect of different packages on spear total sugars (g/100 g.d.w.) during cold storage.

Treatments	Storage periods (in days)						
	0	7	14	21	28	35	42
1993-1994							
Fiber board carton box							
30 x 20 x 10 cm	51.40	43.20	38.40	34.10	28.90	-	-
40 x 30 x 9 cm	51.40	43.90	38.80	34.90	29.80	-	-
45 x 30 x 14 cm	51.40	44.20	40.10	35.70	30.90	-	-
Perforated polyethylene bags							
0.15 %	51.40	47.20	43.10	39.60	35.40	26.20	-
0.30 %	51.40	46.10	41.40	37.80	33.50	-	-
0.45 %	51.40	44.30	39.60	35.30	30.70	-	-
Non-perforated polyethylene bags	51.40	48.30	45.70	42.70	39.50	36.00	25.40
Control	51.40	35.60	24.90	16.70	-	-	-
1994-1995							
Fiber board carton box							
30 x 20 x 10 cm	49.00	40.90	35.30	30.20	23.90	-	-
40 x 30 x 9 cm	49.00	41.20	36.10	31.40	24.60	-	-
45 x 30 x 14 cm	49.00	41.60	36.80	32.10	25.20	-	-
Perforated polyethylene bags							
0.15 %	49.00	45.10	40.60	35.70	30.30	26.90	-
0.30 %	49.00	44.20	39.20	33.80	29.10	-	-
0.45 %	49.00	42.40	37.90	30.70	26.80	29.80	22.10
Non-perforated polyethylene bags	49.00	45.80	41.90	37.30	33.70	-	-
Control	49.00	33.10	20.40	12.60	-	-	-

Table (7): Effect of different packages bags on CO₂ and O₂ (%) during cold storage.

Treatments	Cases	Storage periods in days								
		5	10	15	20	25	30	35	40	45
Perforated bags 0.15%	CO ₂	0.50	0.80	1.10	1.80	2.40	2.90	3.20	-	-
	O ₂	20.30	20.00	18.90	17.60	16.10	15.50	15.00	-	-
0.30%	CO ₂	0.25	0.60	0.62	0.70	0.72	0.90	-	-	-
	O ₂	20.60	20.40	19.30	18.90	18.10	17.20	-	-	-
0.45%	CO ₂	0.20	0.40	0.50	0.60	0.60	0.80	-	-	-
	O ₂	20.60	20.50	19.50	18.90	18.20	17.30	-	-	-
Non-perforated sealed bags	CO ₂	1.60	2.70	4.30	5.90	7.60	9.30	11.30	12.50	14.30
	O ₂	17.80	16.20	14.60	12.20	10.40	8.60	6.20	4.00	2.10
Control	CO ₂	0.03	0.03	0.03	0.03	-	-	-	-	-
	O ₂	20.90	20.90	20.90	20.90	-	-	-	-	-

Concerning the unmarketable spears, it is clear that this character increased gradually either in boxes or bags by the elapse of storage periods. The reasons for this criterion were mentioned before in the explanation of the results of storing the various spear developmental ages. However, the non-perforated polyethylene bags proved to be the most effective ones in minimizing the unmarketable percentage during storage. Non ventilated film bags often maintained fruits in good appearance longer than in ventilated ones. This may be due to the initiated modified atmosphere which characterized with low O₂ and more CO₂. Hence, modified atmosphere storage reduced respiration rates as long as O₂ and CO₂ levels are maintained within levels tolerated by the commodity. Reduced respiration rates were combined with lowering of C₂H₄ production which results in better retention of chlorophyll (*Green color*), texture (less softening and lignifications) and sensory attributes of vegetables (Kader *et al.*, 1989). On storing broccoli in bags to determine the effect of elevated CO₂ concentrations on spear ascorbic acid content, CO₂ reduced the level of ascorbic acid in the packaged spears than the non-packaged ones (Wang, 1979).

The use of non-perforated polyethylene bags proved to be the most promising for maintaining the suitable modified atmosphere for broccoli spears as the concentrations of CO₂ were high and O₂ were low. The question of why the non-perforated polyethylene bags were the best for storing the broccoli spears may find the answer in the following explanation. However, it is known that ethylene is physiologically active in trace amounts (0.1 ppm), loss of chlorophyll and other Features of senescence may be initialed or accelerated when plant tissue is exposed to levels of ethylene. 1 ppm (Watada, 1986 and Kader *et al.*, 1989). Elevation of CO₂ atmosphere inside the bags may prevented to great extent the accumulation of higher levels of ethylene and in the same time counteracted the biological activity of ethylene which enhancing senescence and chlorophyll degradation. In other words, elevated CO₂ atmosphere have been shown to be a compactive inhibitor of the biological action and synthesis of ethylene (Burg and Burg, 1967 and Burg and Burg, 1969). So, the non-perforated polyethylene bags

showed the least loss in weight and unmarketable spears. At the same time, it kept comparatively the highest T.S.S., ascorbic acid, total chlorophyll and total sugars

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تأثير العبوات المختلفة على قابلية أقراص البوركلي للتخزين

عبد النعيم سيد عبد الرحيم أبو الحمد ، عبد المنعم أحمد محمد إسماعيل
قسم البساتين - كلية الزراعة - جامعة الأزهر

تم قطف الأقراص عند عمر ٢٠ يوماً حيث تم تعبئتها في عبوات كرتون ذات أحجام مختلفة بمقاييس ١٠×٢٠×٣٠ سم، ٩×٣٠×٤٠ سم، ٤×٣٠×٤٥ سم بالإضافة إلى تعبئة الأقراص في أكياس مثقبة من البولي إيثيلين مقاس ٣٠×٤٥ سم بمساحات تهوية مختلفة (١٥، ٣٠، ٤٥%) وأكياس غير مثقبة بالإضافة لمعاملة المقارنة وهي غير معبأة، ثم خزنت الأقراص تخزيناً مبرداً على درجة حرارة ٥م ورطوبة نسبية ٩٠-٩٥% حيث تمت دراسة الصفات الطبيعية والكيميائية كل سبعة أيام خلال فترات التخزين وتم الحصول على النتائج التالية:

فاقت عبوات الكرتون كبيرة الحجم كلا الحجمين الآخرين في تقليل نسبة الفقد في الوزن، كما فاقت أيضاً أكياس البولي إيثيلين غير المثقبة الأكياس الأخرى في تقليل هذه النسبة. قللت عبوات الكرتون المختلفة نسبة الأقراص غير الصالحة للتسويق عن المقارنة، وقد وضح أن أكياس البولي إيثيلين غير المثقبة كانت أكثر تأثيراً في تقليل هذه النسبة عن الأكياس المثقبة المختلفة، وعن تلك المعبأة في عبوات الكرتون المختلفة.

أدى استخدام عبوة الكرتون الكبيرة (٤×٣٠×٤٥ سم) أعلى محتوى من المواد الصلبة الذاتية الكلية وحمض الأسكوربيك والكلوروفيلات الكلية والسكريات الكلية في الأقراص بالنسبة لعبوات الكرتون الأخرى، وهذا ما حدث أيضاً بالنسبة لأكياس البولي إيثيلين غير المثقبة بالنسبة للأكياس الأخرى المثقبة.

زادت نسبة ثاني أكسيد الكربون وقلت نسبة الأوكسجين داخل الأكياس غير المثقبة عن الأكياس المثقبة.

وقد أدى استخدام أكياس البولي إيثيلين غير مثقبة إلى أفضل النتائج في هذا

المجال.