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EXTENDING STORAGE PERIOD AND SHELF LIFE AND MAINTAINING QUALITY OF DILL USING MICROPERFORATED POLYPROPYLENE PACKAGES

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ABSTRACT: This investigation was conducted during 2016 and 2017 seasons, at the Laboratory of Horticulture Department, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt, to study the effect of five types of polypropylene packages (non-perforated, perforated with 8, 16, 24 and 32 microholes) on storability and quality of dill during cold storage for 7, 14, 21 and 28 days at 0±1°C, in addition to 2 and 4 days at 10±1°C as shelf life. Weight loss, appearance, off-odor, taste, total chlorophyll, ascorbic acid, soluble solids content (SSC), total sugars content and total phenolic were measured. The results indicated that the microperforated polypropylene package with 24 microholes had the best taste and appearance, and the highest total chlorophyll, ascorbic acid, sugars and phenolic and lowest off-odor during the cold storage period at 0±1 °C for 28 days and shelf life for 4 days at 10 ± 1°C in comparison with the other packages. At the end of cold storage and period of shelf life, the microperforated polypropylene package with 24 microholes maintained the quality of dill.

Key words: Dill, microperforated polypropylene, quality, shelf life, cold storage, ascorbic acid, sugars.

INTRODUCTION

Dill (*Anethum graveolens* L.) is an aromatic herb. It is used for seasoning and flavoring of various foods such as sauces, salads, sea foods, soups and pickled vegetables. Leafy vegetables loss is due to the high metabolism rate which is hastened following harvest. Rapid deterioration of leafy vegetables quality *via* senescence is a serious problem **(Koukounaras *et al.,* 2006)**. Ethylene accelerates degradation of chlorophyll resulting in yellowing the leafy vegetables such as parsley **(Lers *et al.,* 1998)**, coriander **(Jiang *et al.,* 2002)**. Packaging is essential for food protection and preservation and has assumed a multi-functional role by serving as value addition symbol, quality assurance and quantity/ number, ultimately a tool for marketing food products and conveyor of convenience. The packaging importance has gained ground, thanks to the growing awareness and willingness of consumer to pay for hygienic and value produce. Stringent export market needs and increasing exports have influenced the packaging trend. Growing environmental concerns have imposed newer characteristics for package and give an impulse to the eco-friendly packaging materials development. The goal of modified atmosphere packaging in fresh commodities is to generate an atmosphere in the package with high CO_2 and low O_2 concentrations (relative to air) to keep the produce quality at cold temperature (**Zagory, 1998; Sanz *et al.*, 1999**). MAP can be created actively by flushing a mixture of gases inside the package or passively by the respiring commodity (**Church and Parson, 1995**). Modified atmosphere packaging (MAP) of fresh produced focused on matching suitable plastic films to products. Because achieving a favorable modified atmosphere inside the package depends on respiration rate of product, mass of product, surface area of film, thickness of film

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and gas transmission rates of film. A diversity of products needs a diversity of films. The different package sizes for the similar products often needs different packaging films. Proper packaging has eased extension of products shelf life to meet the long distance distribution demands, product quality maintenance by reducing respiration rate, fruit softening and decay, browning reactions, added produce convenience through resealable packages and portion control and enhanced marketing through brands identification and improved the produce visibility **(Zagory, 1997)**.

The objectives of this study are to provide information on the effect of microperforated polypropylene packages on fresh dill quality during cold storage at 0°C for 28 days and shelf life period at 10°C.

MATERIALS AND METHODS

Plant Material and Treatments

Dill cv 'Balady' was planted in a Commercial Farm, Ismailia, Egypt, to produce the plant material that used in postharvest experiment. Dill was harvested on January 2nd, 2016 in the first season and on January 7th, 2017 in the second season. Dill was delivered to the Laboratory of Horticulture Department, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. Dill leaves were inspected visually and defected and blemished leaves were discarded. Five types of packages were used: non-perforated polypropylene package, perforated polypropylene package with 8 microholes (4 on each side of package), perforated polypropylene package with 16 microholes (8 on each side of package), perforated polypropylene package with 24 microholes (12 on each side of package), perforated polypropylene package with 32 microholes (16 on each side of package). The dimensions of all used packages were 17 × 30 cm and the thickness was 40 µm. The diameter of microhole is 540 µm. One hundred gram of dill leaves (20-25 cm long) with green fully was packed in each package, then was closed by a heat sealer. All treatments were made in triplicate and stored at 0±1°C, with 90-95% RH for 7, 14, 21 and 28 days. The dill which was stored at 0°C for 7, 14, 21 and 28 days were kept for 2 and 4 days at 10±1°C, with 80-85% RH, in order to simulate the retail sale period.

Assessment and Measurements

On each day of analysis, 9 replicates were randomly taken out of the 0°C storage from each package, 3 replicates were evaluated at the same day, and 6 replicates kept at 10°C for 2 (3 replicates) and 4 (3 replicates) days as a simulated retail sale period.

Weight loss (%)

The weight of dill packages were measured on zero time and on the day of sampling. During the storage, the weight loss of dill was calculated by determining the changes in weight and calculated as the percentage of initial fresh weight.

Appearance

A group consists of five drilled panelists judged the appearance of dill from each package. The typical characteristics of the dill and the possibilities of impairment were demonstrated before the evaluation started. Visual quality of dill herbs were recorded on 9 to 1 scale, where 9 = excellent (fresh appearance), 7 = very good, 5 = good (limited marketability), 3=fair (limit of usability) and 1 = poor, inedible according to **Koukounaras *et al.* (2008).** The middle numbers were appointed where convenient. The term "storage life" indicate to the time needed for the sample to deteriorate from ranking 9 (field fresh) to 1 (poor).

Taste

The taste assessment was completed by a trained group of 5 peoples in a specially furnisher room with individual booths. The panelists were trained on the sensory features of fresh dill and were experienced in tasting fresh produce. The panel members evaluated 3 replicates for each treatment and used water for washing after tasting dill from each package. Panelists ranked dill for taste on a scale of five to one, where 5 = fully typical, 4 = moderately full, 3 = moderate, 2 = slight and 1 = none **(Elwan *et al.*, 2015).**

Off odor

Off odor was estimated on a scale of five to one, where 5 = severe, 4 = moderately severe, 3 = moderate, 2 = slight and 1 = none **(Elwan *et al.*, 2015)**.

Total chlorophyll contents

Total chlorophyll was extracted (0.5 g) by 80% acetone and measured spectrophotometricaly according to **Lichenthaler and Wellburn (1983)**, then calculated as mg/100 g.

Ascorbic acid content

Dill leaves (10 g) were ground in a mortar with 50 ml of 0.9 M oxalic acid. The mixture was transferred to volumetric flask, then made up to 100 ml with distilled water and filtered by a paper of filter (Whatman No 1), and then ten milliliter of supernatant were titrated to pink color using 0.1% 2,6-dichlorophenolindophenol titration, and then ascorbic acid was calculated and expressed as mg/100 g fresh weight according to **Pearson (1970).**

Soluble solids content

Soluble solids content (SSC) of dill was measured by hand rafractometer according to **AOAC (1996)** expressed as (%) at 20°C.

Total sugars

Five grams of fresh dill were homogenized for two min in 50 ml of 80% ethanol, and then refluxed for thirty minutes, and was centrifuged for 30 min at 10000×g. The residue was exposed to ethanol extraction anther time. The extractions were collected and the alcohol was separated *via* evaporation. The aliquot was filled with distilled water up to 50 ml. The total sugars were determined with phenol–sulfuric acid reagent using spectrophotometer at 480 nm according to **Dubois *et al.* (1956)**.

Total phenolic content

Total phenolic determination was carried out for dill according to **Mazumdar and Majumder (2003)** as described in the following method. Total phenolic was extracted from 5 g of fresh dill (each sample date) with 80% ethanol in boiling water bath and then was cooled to room temperature. After cooling, the extract was centrifuged. The supernatant was evaporated to nearly dryness in a water path, then the residue was dissolved in distilled water and made up to 100 ml with distilled water, from this solution 1.00 ml was taken into test tube, then 0.5 ml of folin ciocalteu's phenol reagent was added. After 5 minutes, 1ml of 15% sodium carbonate was added and then made up to 10 ml with distilled water. The optical density of the blue color was measured through 650 nm wavelength in a spectrophotometer, then calculated as mg/100g fresh weight.

Statistical Analysis

Data were organized in a completely randomized block design (CRBD) with a split plot arrangement the packages were randomly circulated in the main plots and the times of storage were randomly circulated in the sub-plots, with three replications, in which each replicate was considered as a block. Least significance difference (LSD) test was used to compare means at the 5% significance level. Experimental data were statistically evaluated by COStat version 6.303 1998-2004 CoHort software 798 lighthouse Ave PMP 320, Monterey, CA, 93940, USA. Analysis of variance (ANOVA) was achieved to compare results.

RESULTS

Weight Loss (%)

The influences of packages, periods of storage and their interaction on dill weight loss (%) during 28 days at 0°C of cold storage plus 2 and 4 days of shelf life at 10 °C during the two seasons are shown in Fig. 1. The results showed that the perforated polypropylene package with 32 microholes (32 hr.) had the highest weight loss (%) while the perforated polypropylene package with 8 microholes (8 hr.) had the lowest. The weight loss (%) increased with elongation of cold storage and period of shelf life. Concerning the interaction effects on weight loss (%), no weight loss was recorded in the non-perforated polypropylene package and the perforated polypropylene package with 8 microholes during 7 days at 0°C. At the end of storage, the perforated polypropylene package with 32 microholes (32 hr.) had the highest weight loss. However, no significant differences were noticed between the other packages (non-perforated polypropylene package the perforated polypropylene packages with 8, 16 and 24 microholes).

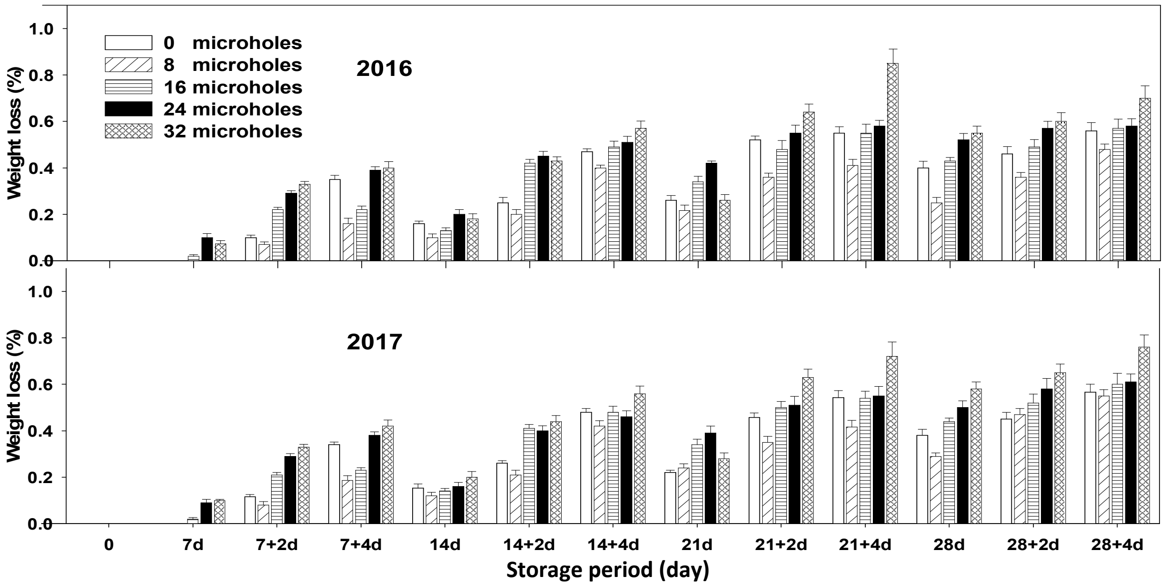

Fig. 1. Effect of microperforated polypropylene packages on weight loss (%) of dill during 2016 and 2017 seasons

Appearance

The results in Table 1 reveal that appearance of dill was significantly affected by packages, storage periods and their interaction during the two seasons (2016-2017) ($p<0.001$). The perforated polypropylene package with 24 microholes (24 hr.) had the highest value of appearance compared with the other packages. The appearance decreased by extension of storage period and this decreasing was marked when the packages were transferred to the retail sale at 10 °C. Regarding the interaction of packages and storage periods, the appearance decreased sharply in non-perforated polypropylene package after 14 days at 0°C plus 2 days at 10°C, then the samples lost its appearance after 21 days at 0°C and 4 days at 10°C. The perforated polypropylene packages with 16 and 24 microholes maintained the appearance of dill at 9 scores (fresh and excellent appearance) after 21 days at 0°C. However, the perforated polypropylene packages with 24 microholes had 5 scores which mean good appearance after 28 days at 0°C plus 2 days at 10°C compared with the other packages.

Off Odor

Results in Table 2 show the effect of packages, storage periods and their interaction on off odor during the two seasons. Non-perforated polypropylene package had the highest off odor while the perforated polypropylene package with 24 microholes had the lowest value. The off odor increased by extension of storage period in both seasons. In regard to the interaction, off odor was detected in non-perforated polypropylene packages after 7 days at 0°C and 2 days at 10 °C then reached to 5 scores (severe) after period of cold storage for 21 days at 0°C. However, off odor was not detected in the perforated polypropylene packages (8, 16, 24 and 32 microholes) until 21 days at 0 °C plus 2 days at 10°C. At the end of storage period, perforated polypropylene package with 24 microholes had 2 scores (slight) in comparison with the other packages.

Taste

Results in Table 3 show the effect of packages, storage periods and their interaction on dill taste during two seasons. The perforated polypropylene package had the highest taste, while the non-perforated polypropylene package had the lowest taste in both seasons. The dill taste decreased gradually during storage periods. Concerning the interaction, the taste reduced severely in non-perforated polypropylene package and then the samples lost its taste after 21 days at 0°C. However, the dill packed in perforated polypropylene packages with 16 and 24 microholes kept its taste (fully typical) up to 21 days of cold storage at 0°C.

Table 1. Effect of microperforated polypropylene packages on appearance of dill during 2016 and 2017 seasons

Treatment	Package					Mean
	Non-perforated	8 holes	16 holes	24 holes	32 holes	
			2016 season			
0 time	9.00	9.00	9.00	9.00	9.00	
7d[1]	9.00a	9.00a	9.00a	9.00a	9.00a	9.00A
7+2d[2]	7.00cd	9.00a	9.00a	9.00a	9.00a	8.60B
7+4d[2]	7.00cd	9.00a	9.00a	9.00a	9.00a	8.60B
14d[1]	7.00cd	9.00a	9.00a	9.00a	9.00a	8.60B
14+2d[2]	4.33gh	7.67bc	9.00a	9.00a	7.67bc	7.53C
14+4d[2]	3.67hi	7.00cd	8.33ab	8.33ab	7.00cd	6.87D
21d[1]	4.33gh	7.00cd	9.00a	9.00a	8.33ab	7.53C
21+2d[2]	3.00ij	6.33de	7.00cd	7.00cd	6.33de	5.93E
21+4d[2]	2.33j	4.33gh	5.00fg	5.00fg	5.00fg	4.33F
28d[1]	1.00k	4.33gh	5.00fg	5.67ef	4.33gh	4.07F
28+2d[2]	1.00k	3.00ij	3.00ij	5.00fg	3.00ij	3.00G
28+4d[2]	1.00k	2.33j	3.00ij	3.00ij	1.00k	2.07H
Mean	**4.22C**	**6.50B**	**7.11A**	**7.33A**	**6.56B**	
			2017 season			
0 time	9.00	9.00	9.00	9.00	9.00	
7d[1]	9.00a	9.00a	9.00a	9.00a	9.00a	9.00A
7+2d[2]	7.00cd	9.00a	9.00a	9.00a	9.00a	8.60AB
7+4d[2]	7.00cd	9.00a	9.00a	9.00a	9.00a	8.60AB
14d[1]	6.33de	8.33ab	9.00a	9.00a	9.00a	8.33B
14+2d[2]	4.33g	7.67bc	8.33ab	9.00a	7.67bc	7.40C
14+4d[2]	3.00h	7.00cd	8.33ab	8.33ab	7.00cd	6.73D
21d[1]	4.33g	7.00cd	9.00a	9.00a	7.67bc	7.40C
21+2d[2]	3.00h	6.33de	6.33de	6.33de	6.33de	5.67E
21+4d[2]	1.67i	4.33g	5.00fg	5.67ef	5.00fg	4.33F
28d[1]	1.00i	4.33g	5.00fg	5.67ef	4.33g	4.07F
28+2d[2]	1.00i	3.00h	3.00h	5.00fg	3.00h	3.00G
28+4d[2]	1.00i	1.67i	3.00h	3.00h	1.00i	1.93H
Mean	**4.06D**	**6.39C**	**7.00B**	**7.33A**	**6.50C**	

The values within a column with different letters are significantly different at P≤ 0.001% according to the LSD multiple range test. 1: Cold storage period, 2: Cold storage period + shelf life.

Table 2. Effect of microperforated polypropylene packages on off odor of dill during 2016 and 2017 seasons

Treatment	Package					Mean
	Non-perforated	8 holes	16 holes	24 holes	32 holes	
			2016 season			
0 time	1.00	1.00	1.00	1.00	1.00	
7d[1]	1.00i	1.00i	1.00i	1.00i	1.00i	1.00H
7+2d[2]	2.00g	1.00i	1.00i	1.00i	1.00i	1.20G
7+4d[2]	3.00d	1.00i	1.00i	1.00i	1.00i	1.40F
14d[1]	2.00g	1.00i	1.00i	1.00i	1.00i	1.20g
14+2d[2]	3.00d	1.00i	1.00i	1.00i	1.00i	1.40F
14+4d[2]	4.00c	1.00i	1.00i	1.00i	1.00i	1.60E
21d[1]	3.00d	1.00i	1.00i	1.00i	1.00i	1.40F
21+2d[2]	4.00c	2.00g	2.00g	2.00g	2.00g	2.40D
21+4d[2]	4.33b	2.00g	2.00g	2.00g	2.00g	2.47D
28d[1]	5.00a	2.00g	2.00g	1.67h	2.33f	2.60C
28+2d[2]	5.00a	2.67e	2.00g	2.00g	2.00g	2.73B
28+4d[2]	5.00a	3.00d	2.67e	2.00g	3.00d	3.13A
Mean	**3.44A**	**1.56B**	**1.47C**	**1.39D**	**1.53B**	
			2017 season			
0 time	1.00	1.00	1.00	1.00	1.00	
7d[1]	1.00h	1.00h	1.00h	1.00h	1.00h	1.00H
7+2d[2]	2.00f	1.00h	1.00h	1.00h	1.00h	1.20G
7+4d[2]	3.00d	1.00h	1.00h	1.00h	1.00h	1.40F
14d[1]	2.00f	1.00h	1.00h	1.00h	1.00h	1.20G
14+2d[2]	3.00d	1.00h	1.00h	1.00h	1.00h	1.40F
14+4d[2]	4.00c	1.00h	1.00h	1.00h	1.00h	1.60E
21d[1]	3.00d	1.00h	1.00h	1.00h	1.00h	1.40F
21+2d[2]	4.00c	2.00f	2.00f	1.67g	2.00f	2.33D
21+4d[2]	4.67b	2.00f	2.00f	2.00f	2.00f	2.53C
28d[1]	5.00a	2.00f	2.00f	1.67g	2.00f	2.53C
28+2d[2]	5.00a	2.67e	2.00f	1.67g	2.00f	2.67B
28+4d[2]	5.00a	3.00d	2.67e	2.00f	3.00d	3.13A
Mean	**3.47A**	**1.56B**	**1.47B**	**1.33C**	**1.50B**	

The values within a column with different letters are significantly different at P≤ 0.001% according to the LSD multiple range test. 1: Cold storage period, 2: Cold storage period + shelf life.

Table 3. Effect of microperforated polypropylene packages on tast of dill during 2016 and 2017 seasons

Treatment	Package					Mean
	Non-perforated	8 holes	16 holes	24 holes	32 holes	
			2016 season			
0 time	5.00	5.00	5.00	5.00	5.00	
7d[1]	5.00a	5.00a	5.00a	5.00a	5.00a	5.00A
7+2d[2]	4.00b	5.00a	5.00a	5.00a	5.00a	4.80B
7+4d[2]	3.33cd	5.00a	5.00a	5.00a	5.00a	4.67B-D
14d[1]	3.67bc	5.00a	5.00a	5.00a	5.00a	4.73BC
14+2d[2]	3.00d	5.00a	5.00a	5.00a	5.00a	4.60CD
14+4d[2]	2.00e	5.00a	5.00a	5.00a	4.67a	4.33E
21d[1]	3.33cd	4.67a	5.00a	5.00a	4.67a	4.53D
21+2d[2]	3.00d	4.00b	4.00b	4.00b	4.00b	3.80F
21+4d[2]	2.00e	4.00b	4.00b	4.00b	4.00b	3.60G
28d[1]	1.00f	4.00b	4.67a	4.67a	4.00b	3.67FG
28+2d[2]	1.00f	3.33cd	3.67bc	4.00b	3.00d	3.00H
28+4d[2]	1.00f	3.00d	3.00d	3.00d	1.00f	2.20I
Mean	**2.69D**	**4.42B**	**4.53A**	**4.56A**	**4.19C**	
			2017 season			
0 time	5.00	5.00	5.00	5.00	5.00	
7d[1]	5.00a	5.00a	5.00a	5.00a	5.00a	5.00A
7+2d[2]	4.00cd	5.00a	5.00a	5.00a	5.00a	4.80AB
7+4d[2]	3.33ef	5.00a	5.00a	5.00a	5.00a	4.67BC
14d[1]	3.67de	3.67de	5.00a	5.00a	5.00a	4.73B
14+2d[2]	3.00fg	5.00a	5.00a	5.00a	5.00a	4.60BC
14+4d[2]	2.00h	5.00a	5.00a	5.00a	4.67ab	4.33D
21d[1]	3.33ef	4.33bc	5.00a	5.00a	4.67ab	4.47CD
21+2d[2]	3.00fg	4.00cd	4.00cd	4.00cd	4.00cd	3.80E
21+4d[2]	1.33i	3.67de	3.67de	4.00cd	4.00cd	3.33F
28d[1]	1.00i	3.67de	4.00cd	4.67ab	3.67de	3.40F
28+2d[2]	1.00i	3.00fg	3.33ef	4.00cd	2.67g	2.80G
28+4d[2]	1.00i	2.67g	2.67g	3.00fg	1.00i	2.07H
Mean	**2.64D**	**4.28B**	**4.39B**	**4.56A**	**4.14C**	

The values within a column with different letters are significantly different at P≤ 0.001% according to the LSD multiple range test. 1: Cold storage period, 2: Cold storage period + shelf life

Total Chlorophyll

Fig. 2 shows the effects of packages, storage duration and their interaction during two seasons on total chlorophyll. The lowest total chlorophyll was recorded in dill packed in non-perforated polypropylene package, while the highest content was recorded in perforated polypropylene package with 24 microholes. The results cleared that total chlorophyll significantly declined with elongation of cold storage and period of shelf life. Also, total chlorophyll was higher at each cold storage period at 0°C and duration of shelf life at 10°C. Concerning the effect of interaction between packages and storage periods, the results indicated that total chlorophyll reduced sharply in non-perforated polypropylene packages with the cold storage at 0°C and period of shelf life at 10°C. At the end of storage period, the perforated polypropylene package with 24 microholes had the highest total chlorophyll.

Ascorbic Acid Content

Table 4 results show the effects of packages, storage duration and their interaction ($p<0.005$) on ascorbic acid content in dill during two seasons. The non-perforated polypropylene package had the lowest ascorbic acid content during the two seasons, while no significant difference was detected between the perforated polypropylene package with 16 and 24 microholes in the first season. However, the perforated polypropylene package with 24 microholes had the highest value in the second season. Ascorbic acid decreased significantly during storage periods. With respect to the interaction, a severely decrease in ascorbic acid was detected in dill packed in the non-perforated polypropylene package during storage periods. After 28 days at 0°C and 4 days as shelf life at 10°C, no significant differences were noticed between the perforated polypropylene packages with 8, 16, 24 and 32 microholes in the both seasons.

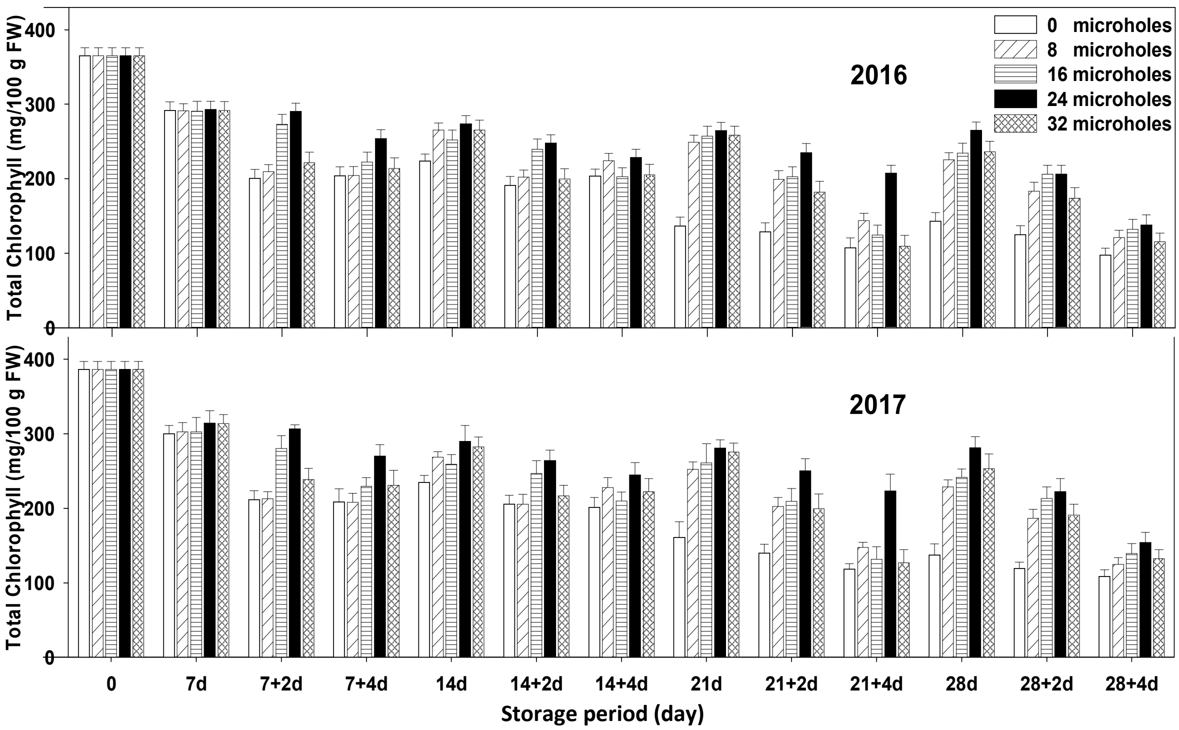

Fig. 2. Effect of microperforated polypropylene packages on total chlorophyll of dill during 2016 and 2017 seasons

Table 4. Effect of microperforated polypropylene packages on ascorbic acid of dill during 2016 and 2017 seasons

Treatment	Package					Mean
	Non-perforated	8 holes	16 holes	24 holes	32 holes	
			2016 season			
0 time	85.26	85.26	85.26	85.26	85.26	
7d[1]	63.09d-g	74.41a	74.54a	73.68ab	63.16d-g	69.78A
7+2d[2]	52.56i-n	65.26b-e	73.69ab	63.09d-g	57.89d-k	62.50B
7+4d[2]	39.93q-s	58.88d-k	50.53k-n	62.08d-h	58.92d-k	54.07C
14d[1]	52.11j-n	60.53d-j	65.80b-d	72.65a-c	64.67c-f	63.15B
14+2d[2]	41.55o-r	52.16j-n	58.75d-k	60.63d-i	52.64i-n	53.14C
14+4d[2]	39.32rs	56.84e-m	56.00g-n	57.82d-l	57.86d-k	53.57C
21d[1]	52.64i-n	54.89g-n	55.76g-n	56.36f-n	52.37i-n	54.40C
21+2d[2]	37.34rs	52.86i-n	52.63i-n	54.64h-n	55.76g-n	50.65C-E
21+4d[2]	40.63p-r	49.41l-o	53.90h-n	57.86d-k	53.57i-n	51.07CD
28d[1]	48.42m-p	52.60i-n	52.63i-n	57.82d-l	52.64i-n	52.82C
28+2d[2]	32.12s	52.79i-n	52.56i-n	52.74i-n	52.56i-n	48.55DE
28+4d[2]	33.64rs	48.32n-q	52.04k-n	52.63i-n	49.01m-p	47.13E
Mean	**44.45C**	**56.58B**	**58.24AB**	**60.17A**	**55.92B**	
			2017 season			
0 time	87.37	87.37	87.37	87.37	87.37	
7d[1]	65.34d-g	78.12a	78.52a	78.41a	66.58d-f	73.39A
7+2d[2]	54.72j-n	68.67cd	77.37ab	67.52de	61.01d-j	65.86B
7+4d[2]	42.07pq	62.14d-j	54.06j-n	66.36d-f	61.89d-j	57.31C
14d[1]	53.74j-n	63.83d-i	69.37b-d	76.97a-c	67.68de	66.32B
14+2d[2]	43.07o-q	55.21j-n	62.07d-j	64.70d-h	55.40i-n	56.09CD
14+4d[2]	39.71qr	54.92j-n	59.24e-m	61.81d-j	54.54j-n	54.04C-E
21d[1]	54.55j-n	57.87g-n	59.01f-m	61.03d-j	55.06j-n	57.50C
21+2d[2]	38.81qr	55.69i-n	55.73i-n	60.15e-k	54.30j-n	52.94DE
21+4d[2]	38.96qr	52.15k-n	53.91j-n	59.29e-l	52.02k-n	51.27EF
28d[1]	49.88n-p	55.46i-n	55.76i-n	61.70d-j	55.21j-n	55.60CD
28+2d[2]	33.26r	55.50i-n	55.54i-n	56.47h-n	54.98j-n	51.15EF
28+4d[2]	32.75r	50.80m-o	54.79j-n	56.13i-n	51.20l-o	49.13F
Mean	**45.57D**	**59.20BC**	**61.28B**	**64.21A**	**57.49C**	

The values within a column with different letters are significantly different at P≤ 0.001% according to the LSD multiple range test. 1: Cold storage period, 2: Cold storage period + shelf life.

Soluble Solids Content (SSC)

The results in Table 5 show the effect of packages, storage period and their interaction on SSC of dill. Non-perforated polypropylene package had the lowest SSC compared with the other packages. No significant difference was observed between the perforated polypropylene package with 24 microholes and the perforated polypropylene package with 32 microholes. Also, no significant difference was noticed between the perforated polypropylene package with 8 microholes and the perforated polypropylene package with 16 microholes. However, the perforated polypropylene package with 32 microholes had the highest SSC. No clearly trend was observed in SSC during the duration of storage. However, the highest SSC was detected after period of cold storage for 21 days in both seasons. In regard to interaction, after 28 days at 0°C and 4 days at 10°C, non-perforated polypropylene package had the lowest SSC followed by perforated polypropylene package with 8 microholes while no significant differences were detected between the perforated polypropylene packages with 16, 24 and 32 microholes.

Total Sugars

Fig. 3 illustrates the effects of packages, storage periods and their interaction ($p<0.001$) on dill total sugar contents after 28 days of cold storage at 0°C and 4 days of shelf life at 10°C during two seasons. The perforated polypropylene package with 24 microholes maintained the highest total sugars compared with the other packages. Total sugars decreased significantly during storage duration. Concerning the interaction, a sharp decrease in total sugars was detected in dill stored in non-perforated polypropylene package during the storage periods. At the end of storage, dill packed in the perforated polypropylene package with 24 microholes had the highest total sugars followed by the perforated polypropylene package with 32 microholes, while the lowest total sugars were recorded in dill packed in non-perforated polypropylene package.

Total Phenolic

The effect of packages, duration of storage and their interaction during both seasons was illustrated in Fig. 4. The results showed that the highest total phenolic was recorded in dill packed in the perforated polypropylene package with 24 microholes while the lowest was detected in non-perforated polypropylene package. Total phenolic reduced gradually with prolongation of storage duration at 0°C and period of shelf life at 10°C. At the end of storage, a reduction in total phenolic was measured in all packages, but this reduction was higher in dill packed in non-perforated polypropylene package.

DISCUSSION

Dill is one of leafy vegetables which lose water at a higher rate than tubers and bulbs vegetables or soft fruit because are extremely vulnerable **(Kays and Paull, 2004)**. The quality of most vegetables and fruit decreased very fast with small losses of moisture. In general, a loss of 3.00 to 10.00% may render a lot of horticultural crops unacceptable (**Robinson *et al.*, 1975)**. This study takes this into account, the weight loss of dill significantly reduced by perforated polypropylene packages. The weight loss ranged from 0.00 to 0.85% and 0.00 to 0.76% in both seasons, respectively. The highest weight loss (%) in the perforated polypropylene packages with 32 microholes may attribute to the effect of higher microholes number on water loss. The effects of perforated polypropylene packages with 8, 16 and 24 microholes on decreasing dill weight loss (%) may attribute to reduce the transpiration rate by increasing water vapor pressure around the product and relative humidity inside the packages **(Elwan *et al.*, 2015)**. Also, the reduction in weight loss (%) of dill packed in perforated polypropylene packages with 8, 16 and 24 microholes could be due to less oxygen, which reduced the respiration rate, thereby lowering the loss of moisture by transpiration **(Nath *et al.*, 2011).** This has been detected as a general effect of modified atmosphere packaging (MAP) on dill **(Sakaldas *et al.*, 2010)**, snap bean **(Kinyuru *et al.*, 2011)**, green bean **(El-Bassiouny, 2003)** and broccoli **(Fernandez-Leon *et al.*, 2013a)**.

The worst dill appearance was observed in non-perforated polypropylene package. This result may be due to the higher respiration rate and was not caused by weight loss because the weight loss in this package was low. This result is in agreement with the result of **El-Bassiouny (2003)** on snap beans, **Lucera *et al.* (2011)** on

Table 5. Effect of microperforated polypropylene packages on SSC of dill during 2016 and 2017 seasons

Treatment	Package					Mean
	Non-perforated	8 holes	16 holes	24 holes	32 holes	
			2016 season			
0 time	4.00	4.00	4.00	4.00	4.00	
7d[1]	3.00l	4.00d-g	4.00d-g	4.50a-c	3.80e-h	3.86B-E
7+2d[2]	3.50h-k	3.00l	4.53ab	4.00d-g	4.00d-g	3.81C-E
7+4d[2]	3.53h-j	3.80e-h	3.70g-i	4.00d-g	4.00d-g	3.81C-E
14d[1]	3.83e-h	4.00d-g	3.17j-l	4.13c-f	4.500a-c	3.93A-D
14+2d[2]	3.67g-i	4.00d-g	4.00d-g	4.00d-g	4.00d-g	3.93A-C
14+4d[2]	3.13kl	3.80e-h	3.77f-i	3.87e-h	4.00d-g	3.71E
21d[1]	3.83e-h	4.00d-g	4.00d-g	4.00d-g	4.50a-c	4.07A
21+2d[2]	3.00l	3.40i-k	3.00l	4.00d-g	4.00d-g	3.48F
21+4d[2]	3.00l	4.00d-g	3.80e-h	4.00d-g	4.50a-c	3.86B-E
28d[1]	3.17j-l	4.00d-g	4.00d-g	4.17b-e	4.83a	4.03AB
28+2d[2]	2.93l	3.83e-h	4.00d-g	4.00d-g	4.00d-g	3.75DE
28+4d[2]	2.87l	3.67g-i	4.33b-d	4.00d-g	4.00d-g	3.77C-E
Mean	**3.29C**	**3.79B**	**3.86B**	**4.06A**	**4.18A**	
			2017 season			
0 time	4.10	4.10	4.10	4.10	4.10	
7d[1]	3.00no	4.00c-h	4.00c-h	4.30bc	4.03c-g	3.87a-d
7+2d[2]	3.33k-o	3.20l-o	4.27b-d	4.00c-h	4.00c-h	3.76CD
7+4d[2]	3.40j-n	3.13no	3.93c-i	4.20b-e	3.87d-i	3.71DE
14d[1]	3.70g-k	4.00c-h	3.17m-o	4.20b-e	4.50ab	3.91A-C
14+2d[2]	3.60h-l	3.87d-i	3.87d-i	4.20b-e	4.13b-f	3.93A-C
14+4d[2]	3.13no	3.80e-j	3.60h-l	4.00c-h	4.00c-h	3.71DE
21d[1]	3.77f-j	4.00c-h	4.00c-h	4.10b-g	4.33bc	4.04A
21+2d[2]	3.00no	3.40j-n	3.20l-o	4.00c-h	4.17b-f	3.55E
21+4d[2]	3.00no	4.00c-h	3.70g-k	4.17b-f	4.50ab	3.87A-D
28d[1]	2.93o	4.00c-h	4.00c-h	4.17b-f	4.77a	3.97AB
28+2d[2]	3.00no	3.83e-i	4.07c-g	4.00c-h	4.20b-e	3.82B-D
28+4d[2]	2.93o	3.57i-m	4.00c-h	4.10b-g	4.30bc	3.78CD
Mean	**3.23C**	**3.73B**	**3.81B**	**4.12A**	**4.23A**	

The values within a column with different letters are significantly different at P≤ 0.001% according to the LSD multiple range test. 1: Cold storage period, 2: Cold storage period + shelf life.

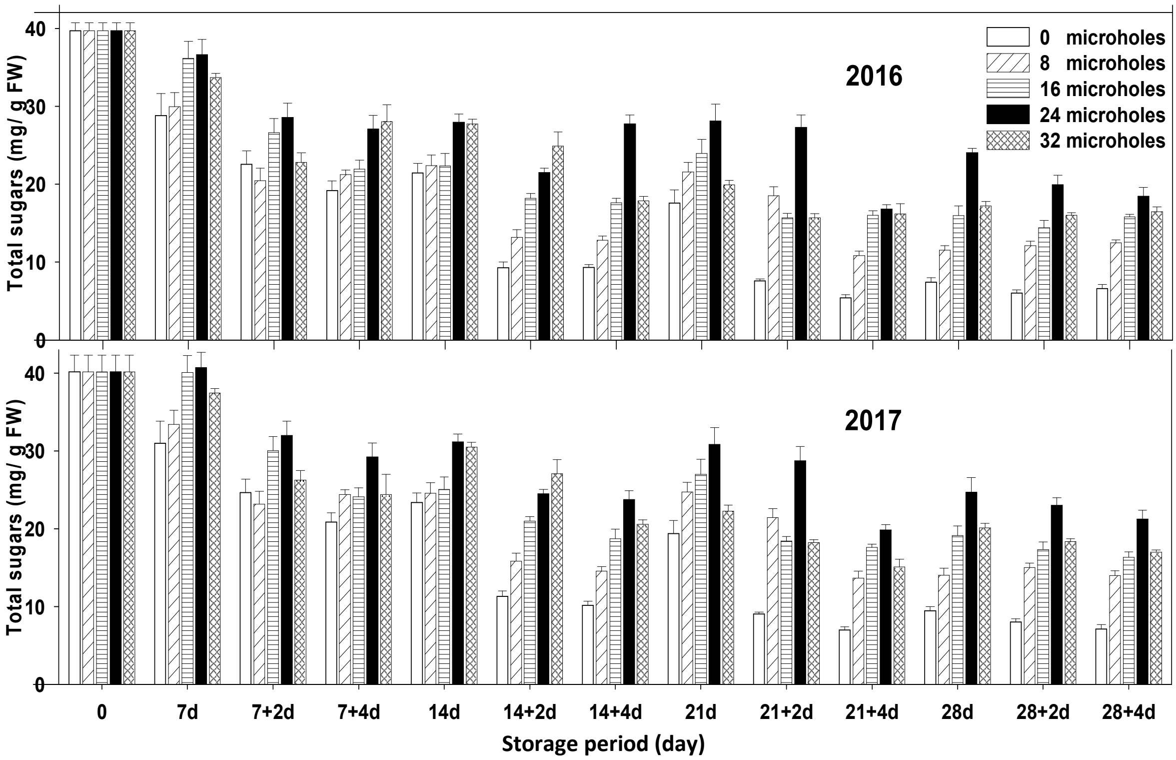

Fig. 3. Effect of microperforated polypropylene packages on total sugars of dill during 2016 and 2017 seasons

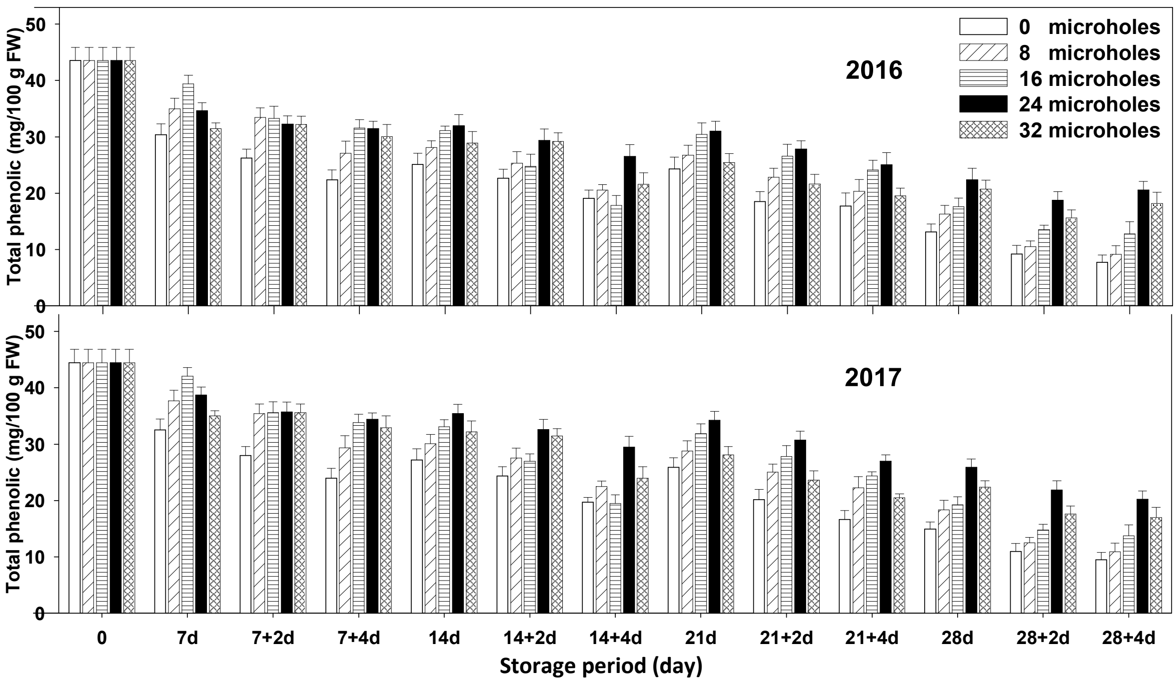

Fig. 4. Effect of microperforated polypropylene packages on total phenolic of dill during 2016 and 2017 seasons

fresh-cut green beans and **Elwan *et al.* (2015)** on snap peas. The best appearance was observed in the perforated polypropylene package with 24 microholes (24 hr.). The good visual quality has been recorded in modified atmosphere packaging **(Sakaldas *et al*., 2010).** This result suggests that the perforated polypropylene package with 24 microholes (24 hr.) maintained the quality of dill by gas composition inside the package.

The highest off odor was detected in non-perforated polypropylene package. The increase in off odor into this package may attribute to the decrease in O_2 and the increase in CO_2 concentrations by increasing the respiration rate which triggers anaerobic conditions, thus the anaerobic respiration quickly destroys the quality of produce by tissue breakdown, accumulation of acetaldehyde and ethanol and development of off-odor **(Elwan *et al.*, 2015)**. The tissue will start anaerobic respiration when the oxygen partial pressure in MAP reduces below the threshold limit of fermentation which produces off odors **(Soliva-Fortuny *et al.*, 2004)**. Off odor was detected in sealed polyethylene package during storage period of green beans **(El-Bassiouny, 2003).** The lowest off odor was recorded in the perforated polypropylene package with 24 microholes. This indicates that this package provides a good gas composition by its appropriate permeability, depending on the number and diameter of microholes.

The flavor of dill is an important quality attributes, packed dill in the perforated polypropylene package with 24 microholes had the best taste while those packed in non-perforated polypropylene package had the worst taste. Similarly, **Elwan *et al.* (2015)** stated that the better taste of sugar snap peas was obtained with micro-perforated polypropylene with 12 microholes compared to non-perforated polypropylene package which resulted in lost the sugar snap peas taste at the end of storage time. These results designate that the perforated polypropylene package with 24 microholes preserved the quality of dill.

Chlorophyll is the importance factor to judge the quality of leafy vegetables. Modified atmosphere packaging delayed the decline of dill chlorophyll content (**Sakaldas *et al.,* 2010**). In this study, dill packed in the perforated polypropylene package with 24 microholes had the highest total chlorophyll content. This result is in harmony with the result of **Nath *et al.* (2011)** on broccoli and **Elwan *et al.* (2015)** on sugar snap peas. The quicker loss in total chlorophyll was observed in dill packed in non-perforated polypropylene package which had the lowest total chlorophyll during storage and duration of shelf life. The effect of non-perforated polypropylene package may be due to the accumulation of CO_2 *via* increasing the respiration rate, which results in the chlorophyll degradation. Also, the reduction in total chlorophyll is considered typical during the senescence process **(Gross, 1991).**

The reduction of ascorbic acid during storage period may attribute to the oxidation by enzymes such as polyphenol oxidase and ascorbic acid oxidase which reduce the ascorbic acid of vegetables (**Mapson (1970)**, and convert it into dehydroascorbic acid (**Albuquerque *et al.,* 2005**). The highest ascorbic acid content in packed dill in perforated polypropylene package with 24 microholes may be attributed to the atmospheric oxygen limitation available for oxidation. The same result was informed by **Kinyuru *et al.* (2011)** on snap beans, **Fernandez-Leon *et al.* (2013a,b)** on broccoli and **Elwan *et al.* (2015)** on sugar snap peas.

The lowest SSC was observed in packed dill in non-perforated polypropylene package. This reduction in SSC may be due to the effect of more carbon dioxide and less oxygen in non-perforated package, generating a high rate of respiration **(Del-Valle *et al.,* 2009)**, which resulting in sugars consumption *via* glycolysis and hydrolysis reactions **(Bodelon *et al.,* 2010).** On the other hand, perforated polypropylene packages with 24 and 32 microholes were more effective in keeping SSC by reducing the respiration rate of dill.

MAP retards the loss of sugars by reducing respiration rate **(Elwan *et al.*, 2015)**. In this study, the highest total sugars were recorded in dill stored in perforated polypropylene package with 24 microholes. Also, the perforated polypropylene packages decreased CO_2 level and postponed carbohydrate metabolism (**Aday *et al.,* 2011**). Similarly **Escalona *et al.* (2004)** on fennel and **Gomez and Artes (2005)** with celery. The sharp decrease in total sugars content of stored dill in non- perforated polypropylene package may be due to the consumption of sugars by the higher respiration rate.

Modified atmosphere packaging prevented the phenolic compounds degradation (**Sakaldas *et al.,* 2010**). The perforated polypropylene package with 24 microholes had the highest total phenolic of dill. This result could be attributed to low oxygen and high carbon dioxide which caused a decrease in activities of polyphenol oxidase and peroxidase, thus preventing the phenolic degradation **(Saxena *et al.*, 2009)**.

Conclusion

The perforated polypropylene package with 24 microholes greatly extended the storage period of dill at 0°C for 28 days and shelf life at 10°C for 4 days with good appearance and taste and had the highest value for each of total chlorophyll, ascorbic acid, sugars and phenolic and the lowest off-odor.

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زيادة فترة التخزين والعرض والحفاظ على جودة الشبت باستخدام عبوات البولى بروبيلين المثقبة تثقيباً دقيقاً

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أجريت هذه الدراسة خلال موسمى ٢٠١٦ و ٢٠١٧م فى معمل قسم البساتين كلية الزراعة جامعة قناة السويس، الإسماعيلية، مصر، وذلك لدراسة تأثير خمس عبوات من البولى بروبيلين (بدون تثقيب ومثقبة بـ ٨ ، ١٦، ٢٤ و ٣٢ ثقباً دقيقاً) على القدرة التخزينية وجودة الشبت خلال التخزين المبرد على درجة صفر مئوى لمدة ٧ ، ١٤ ، ٢١ و ٢٨ يوماً بالإضافة إلى ٢ و ٤ أيام على درجة ١٠ مئوى كفترة عرض بعد التخزين المبرد، وتم دراسة الفقد فى الوزن والمظهر والرائحة والطعم والكلوروفيل الكلى وحامض الأسكوربك ومحتوى المواد الصلبة والسكريات الكلية والفينولات الكلية، أوضحت النتائج أن عبوات البولى بروبيلين المثقبة ٢٤ ثقباً أعطت أفضل مظهر وطعم بالإضافة إلى أعلى محتوى من الكلورفيل الكلى وحامض الأسكوربك والسكريات الكلية والفينولات الكلية خلال فترة التخزين المبرد لمدة ٢٨ يوماً وفترة البقاء لمدة ٤ أيام على ١٠°م مقارنة بالعبوات الأخرى، أيضاً حافظت هذه العبوة على جودة الشبت حتى نهاية فترة التخزين المبرد و فترة العرض.

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