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Quality and Storability of Baby Pea-Shoots as Affected by Passive Modified Atmosphere and Storage Temperatures

[1]Mona I. Abd El-Rehim, [2]M.M.F. Abdallah, [2]A. Abou El-Yazied and [1]R.E.I. El-Bassiuony

[1]*Vegetable Handling Res. Dept., Hort. Res. Institute, ARC, Giza, Egypt*
[2]*Hort. Dept., Fac. of Agric., Ain Shams Univ., Shoubra El-Kheima, Egypt*

ABSTRACT

Baby pea (*Pisum sativum* L.) shoots as a new ready to eat baby leaf vegetable sprouts has a little information available about it, and since it is a fresh herb it have very short storage period after harvest. In this context we determined the effects of different passive modified atmosphere packaging applications for prolonging the shelf life of baby - pea shoots. For this purpose, the performances of modified atmosphere packaging based on low density polyethylene (LDPE) with different perforations (without, with 4 perforations and 8 perforations/package) was examined at different storage temperatures (0-1°C and 4-5°C) with 90-95% RH for 4, 8, 12, 16 and 20 days respectively. Some quality parameters, such as weight loss, visual quality (graded to scale), decay, and off-odor, were evaluated on pea shoots packages. In addition, the atmosphere composition inside the packages was measured at each observation.

Data revealed that baby - pea shoots packaged in LDPE film bags stored at 0ºC in both package areas (500 cm^2 and 600 cm^2) without perforations or with 4 and 8 perforations/package maintained good quality and shelf life throughout 16 days. Baby - pea shoots stored at 5ºC in both package areas without perforations maintained good quality and shelf life throughout 12 days and 8 days for packages with 4 and 8 perforations/package.

Key words: Baby pea shoots, MAP, storage temperature, package, perforations, and quality parameters.

Introduction

Pea shoots are a new option as ready-to-eat baby-leaf vegetable (Santos *et al*., 2014). Pea shoots were recently presented as a ready-to-eat vegetable, and are recognized as a popular specialty vegetable in some parts of Asia and Africa that is gaining popularity in the United States and Europe (Miles & Sonde, 2003).

The consumption of leaves of the pea plants, also known as pea shoots, is not as common as eating the peas. They are harvested in a very early maturation stage, when the leaves and tendrils are tender, crispy and have an intense pea flavor. This baby-leaf green leafy vegetable can be eaten raw in salads, or cooked with others ingredients (Miles & Sonde, 2003). Accordingly to Miles and Sonde (2003), pea shoots are a very perishable product with a high market value, when compared to other common leafy vegetables. As a minimally processed vegetable, pea leaves can be packed solely or in ready-to-eat salad mixtures and their quality and safety is strictly dependent on the maintenance of refrigerating conditions during storage (Rico *et al*., 2007).

Specific scientific data regarding the nutritional composition of pea shoots is scarce, being most of the available information based in the generalization of the green leafy vegetables composition (Miles & Sonde, 2003).

Storage temperature is one of the most important factors affecting the postharvest physiology and storage behavior of produce. In general, low temperature storage can reduce quality loss and extend shelf life by depressing rates of respiration, senescence, and growth of spoilage microorganisms (Manolopoulou *et al*., 2010; Spinardi and Ferrante, 2012). Optimum storage temperature varies depending on the fruit or vegetable. For some chilling sensitive fruits and vegetables, the use of low temperature storage adversely affects quality attributes and causes deterioration more rapidly (Galvez *et al*., 2010; Paull, 1999). Thus, the selection of optimum storage temperature is crucial.

Packaging of leafy vegetables in trays or pouches eases the handling of the produce in the distribution chain, reduces loss of humidity, prevents spoilage, and prolongs shelf-life, if the package atmosphere is modified to an optimum level (Kim *et al*., 2004).

Modified atmosphere packaging (MAP) is an effective technology for maintaining freshness and prolonging shelf life of produce, which has been successfully applied in fresh and minimally processed produce, such as lettuce (*Lactuca sativa* L.), amd spinach (*Spinacia oleracea* L.) (Sandhya, 2010). There are many factors influencing package atmosphere of products, including product respiration rate, packaging film oxygen transmission rate (OTR), product weight, package surface area, storage temperature and relative humidity (Sandhya, 2010). In food supply chains, package size and product weight are often pre-determined. Selecting a

Corresponding Author: Mona I. Abd El-Rehim,Vegetable Handling Res. Dept., Hort. Res. Institute, ARC, Giza, Egypt
E-mail: mona_rehim@hotmail.com

packaging film with suitable OTR to match the product respiration rate is the best way to maintain quality and extend shelf life of produce.

MAP in combination with low temperature storage is an effective tool to prolong shelf-life of leafy vegetables by decreasing oxygen (O_2) and increasing carbon dioxide (CO_2) concentrations inside the package (Escalona *et al*., 2006; Mahajan *et al*., 2007; Kalio, 2008). These conditions delay senescence and slow down the breakdown of green chlorophyll pigments, and hence the yellowing of the green tissues (Page *et al*., 2001; Toivonen and Brummell, 2008). However, this beneficial effect of MAP can easily be lost if the packaged product create too low O_2 and too high CO_2 concentrations inside the packages (Martinez-Sanchez *et al*., 2006). Eventually off-odors develop, which may not be apparent at purchase (Nielsen *et al*., 2008).

Currently, there is no baby - pea shoots are commercially available in the food supply chains in Egypt due to their perishability and high price. Little information is available on optimal storage temperature and packaging film of baby - pea shoots. Therefore, the objectives of this study were to optimize storage temperature; and to evaluate the effect of different passive modified atmosphere packaging; on maintaining quality and prolonging shelf life of pea shoots.

Material and Methods

Plant material

Pea (*Pisum sativum* L.) seeds were soaked overnight in a tap water before sowing at mid-October and performed directly using a plant density of 300g of seeds per m^2 in the experimental farm of faculty of agriculture, Ain Shams University, Shoubra El-Khima, Kalubia governorate, Egypt.

Sample preparation

Fresh baby tender pea shoots were harvested manually harvested using sharp knife. Harvesting started after 2 weeks from planting seeds at the early morning and transported immediately to the organic and sprout production laboratory of Horticulture Dept., Ain Shams University. shoots with defects such as bruising or discoloration were removed by hand, then the shoots were washed in a tap water to remove any residues then precooled using cooled water for 5 min. to remove field heat. The excess surface water remaining on the leaves of the products was removed by left the shoots for air drying. Baby - pea shoots were transported to the vegetable handling laboratory, ARC to packed and stored under a refrigerated condition using ice boxes and kept overnight at 0-2ºC and till process as follows.

Baby - pea shoot samples (100 g each) were packaged in sealed bags prepared with low density polyethylene (LDPE) films (25 µm) with 3 different gas permeabilities (with no perforation, 4 and 8 perforations/package "hole diameter 8 mm") and two bag areas (500 cm^2 "20 × 25" and 600 cm^2 "20 × 30"). The bags were stored at 0°C or 5ºC and 90 – 95% relative humidity for 20 days for subsequent evaluation on product quality every 4 days.

Data recorded

Headspace analysis:

The in–package atmosphere (O_2, CO_2) was measured during storage using a headspace gas analyzer (DualTrak model 902D gas analyzer (Quantek Instruments, USA)) drawing up to 2 mL of air samples. Sampling took place with a hypodermic needle through a septum pasted on the packaging. At each sampling day, 3 packages from each MAP condition were measured. O_2 and CO_2 values were expressed as percentage.

Sensory assessments:

Sensory assessments were carried out at 4-day intervals. Baby - pea shoots from 3 packages were combined and examined at the beginning of the experiment and during the storage period. Panel members were requested to assess baby - pea shoots. Quality measurement was measured during the storage periods as follows:
Visual quality: was evaluated considering freshness, appearance, color uniformity, and brightness following a 9 point rating scale where 9 = excellent, 7 = good, 5 = fair (limit of consumer acceptability), 3 = poor and 1 = extremely poor (Medina *et al*., 2012).
Decay: was estimated visually using scores described by Kader *et al*., (1973) on 5 – 1 scale, with reference points of 5, severe; 4, moderately severe; 3, moderate; 2, slight and 1, none. This depends on the morphological effect such as color change of leaves, any microorganism effect, smell and decay percentage on plants.
Off-odors: (just after opening the bag and again 5 min later) using a 5 point scale where 5 = severe, 3 = moderate and 1 = none. This scale depends on unlike or bad smell (El-Bassiouny, 2003).
Statistical analysis:

The experiment was arranged as a factorial experiment in a completely randomized deign. Duncan's multiple range test at 5% level was used in the experiment to verify the differences between means of the treatments (Snedecor and Cochran, 1982).

Result and Discussion

Effect of different storage temperatures, package areas and passive MAP treatments on atmosphere inside packages

The changes in headspace atmospheres of packaged baby - pea shoots were presented in Tables 1 & 2. Oxygen inside the packages were not significantly affected by storage temperature or package area (Table 1), whereas carbon dioxide affected by storage temperature (Table 2).

Oxygen percentages inside packages were 13.92 % at the beginning of the storage period and end with 6.01% after 20 days of storage (Table 1), whereas carbon dioxide were 3.35% at the beginning of the storage period and 9.91 after 20 days of storage.

Table 1: Effect of different storage temperature, package areas and passive MAP on oxygen (%) of baby - pea shoots (combined analysis of two seasons).

Storage temperature	Package area (cm2)	No. of perforations/package	Storage period (days) 4	8	12	16	20	Mean
At 0ºC + 95% RH	500 cm2	Zero perforation	6.46 r:x	4.76 u:z	3.80 x:z	2.50 z	1.60	3.82 de
		4 perforations	18.93 ab	15.73 c:g	13.07 g:j	10.27 j:p	7.10 p:w	13.02 b
		8 perforations	19.83 a	18.60 a:d	16.90 a:f	12.23 h:k	10.87 i:o	15.69 a
		Mean	15.08 AB'	13.03 B:D'	11.26 D:F'	8.33 GH'	6.52 HI'	10.84 A"
	600 cm2	Zero perforation	7.83 o:u	6.80 q:x	5.90 s:y	5.43 t:z	4.73 u:z	6.14 cd
		4 perforations	19.00 ab	15.53 d:g	11.20 i:n	8.30 n:t	7.10 p:w	12.23 b
		8 perforations	19.40 ab	18.83 a:c	12.00 h:l	11.43 i:n	8.60 m:t	14.05 ab
		Mean	15.41 A'	13.72 A:C'	9.70 FG'	8.38 GH'	6.81 HI'	10.81 A"
	Mean		15.24 A	13.38 B	10.48 D	8.36 E	6.66 FG	10.83 A
At 5ºC + 95% RH	500 cm2	Zero perforation	4.36 v:z	3.93 w:z	2.60 z	1.13	1.50	2.70 e
		4 perforations	13.87 f:i	10.43 j:o	8.83 l:s	5.10 u:z	3.90 x:z	8.42 c
		8 perforations	18.23 a:d	17.67 a:e	11.83 h:l	9.50 k:r	7.23 p:v	12.89 b
		Mean	12.16 C:E'	10.68 EF'	7.75 GH'	5.24 IJ'	4.21 J'	8.00 A"
	600 cm2	Zero perforation	4.633 v:z	3.13 yz	2.70 z	2.56 z	1.40	2.88 e
		4 perforations	16.63 b:f	14.97 e:h	10.20 j:p	9.16 k:r	8.40 m:t	11.87 b
		8 perforations	17.80 a:e	17.50 a:e	11.57 i:m	10.13 j:p	9.73 k:q	13.35 ab
		Mean	13.02 B:D'	11.87 C:E'	8.15 GH'	7.28 HI'	6.51 HI'	9.36 A"
	Mean		12.59 BC	11.27 CD	7.95 EF	6.26 G	5.36 G	8.68 A

***Table 1:** Cont.*

Storage temperature	No. of perforations/package	Storage period (days) 4	8	12	16	20	Mean
At 0ºC + 95% RH	Zero perforation	7.15 ij	5.78 jk	4.85 kl	3.96 k:m	3.16 l:n	4.98 D
	4 perforations	18.97 a	15.63 bc	12.13 e	9.28 hi	7.10 ij	12.62 B
	8 perforations	19.62 a	18.72 a	14.45 cd	11.83 ef	9.73 f:h	14.87 A
At 5ºC + 95% RH	Zero perforation	4.50 kl	3.53 l:n	2.65 l:n	1.85 mn	1.45 n	2.79 E
	4 perforations	15.25 c	12.70 de	9.51 gh	7.13 ij	6.15 jk	10.15 C
	8 perforations	18.02 a	17.58 ab	11.70 e:g	9.81 f:h	8.48 hi	13.12 B
Package area (cm2)	**No. of perforations**	**Storage period (days) 4**	**8**	**12**	**16**	**20**	**Mean**
500 cm2	Zero perforation	5.41 jk	4.35 j:l	3.20 k:n	1.81 mn	1.55 n	3.26 d
	4 perforations	16.40 bc	13.08 de	10.95e:g	7.68 hi	5.50 j	10.72 c
	8 perforations	19.03 a	18.13 ab	14.37 cd	10.87 fg	9.05 gh	14.29 a
	Mean	13.62 A	11.86 B	9.50 C	6.78 EF	5.36 F	9.42 A
600 cm2	Zero perforation	6.23 ij	4.96 j:l	4.30 j:l	4.00 j:m	3.06 l:n	4.51 d
	4 perforations	17.82 ab	15.25 c	10.70 fg	8.73 gh	7.75 hi	12.05 bc
	8 perforations	18.60 ab	18.17 ab	11.78 ef	10.78 fg	9.16 gh	13.70 ab
	Mean	14.22 A	12.79 AB	8.92 CD	7.83 DE	6.66 EF	10.09 A
Mean	Zero perforation	5.82 FG	4.65 GH	3.75 HI	2.90 I	2.30 I	3.89 C
	4 perforations	17.11 B	14.17 C	10.82 D	8.20 E	6.62 F	11.39 B
	8 perforations	18.82 A	18.15 AB	13.07 C	10.82 D	9.10 E	13.99 A
Mean		13.92 A	12.32 B	9.21 C	7.31 D	6.01 E	

Number of perforations/package had a significant effect on atmosphere inside the package. Packages without any perforations experienced a rapid depletion of O_2 (3.89%) and accumulation of CO_2 (9.29%), with the low O_2 (2.3%) and high CO_2 (12.63%) within the packages at the end of 20-day storage. In contrast, packages with 4 and 8 perforations maintained higher levels of oxygen (11.39 and 13.99%, respectively) and higher concentrations of carbon dioxide (9.39 and 7.73%, respectively) at the end of 20-day storage.

The interaction between storage temperature and package area showed no differences between treatments for oxygen percentage inside the package, but was significantly differ for carbon dioxide percentage with the higher concentration in packages with both areas (500 cm^2 and 600 cm^2) stored at 5ºC compared with

0ºC. For the interaction between storage temperature and number of perforation, data showed that oxygen percentage was higher in packages with 8 perforations and stored at 0ºC and 5ºC (14.87% and 13.12%, respectively) and was lower in packages without perforations and stored at 5ºC (2.79%). Conversely, carbon dioxide percentage was higher in packages without perforations and stored at 5ºC (10.26% and 8.22%) and 0ºC (8.33%). The lower percentage of CO_2 was found packages in with 8 perforations and stored at 0ºC.

The interactions between package area and number of perforations/package showed significant differences between treatments for oxygen percentage inside package. As the number of perforations increased, oxygen percentage increased with the highest percentage in packages with 8 perforations and stored at 0ºC and 5ºC without significant differences between them. Conversely, carbon dioxide percentage was higher in packages without perforations and the lowest values were found in packages with 8 perforations.

Table 2: Effect of different storage temperature, package areas and passive MAP on carbon dioxide (%) of baby - pea shoots (combined analysis of two seasons).

Storage temperature	Package area (cm2)	No. of perforations/package	Storage period (days)					Mean
			4	8	12	16	20	
At 0ºC + 95% RH	500 cm2	Zero perforation	5.66 v:z	8.10 n:s	9.66 h:o	11.43 d:g	12.53 b:d	9.48 a
		4 perforations	1.30	6.03 u:z	7.56 p:u	8.86 j:q	9.06 i:p	6.56 b
		8 perforations	1.23	3.06	4.20	5.96 u:z	6.30 t:y	4.15 de
		Mean	2.73 LM'	5.73 HI'	7.14 FG'	8.75 DE'	9.30 CD'	6.73 AB"
	600 cm2	Zero perforation	4.40 z	5.73 v:z	6.76 r:x	9.23 i:p	9.83 g:m	7.19 b
		4 perforations	1.73	5.10 x:z	5.33 w:z	5.86 u:z	6.90 r:w	4.98 cd
		8 perforations	1.40	1.63	3.70	4.20	6.43 s:x	3.47 e
		Mean	2.51 M'	4.15 K'	5.26 IJ'	6.43 GH'	7.72 EF'	5.21 B"
	Mean		2.62 H	4.94 F	6.20 E	7.59 D	8.51 C	5.97 B
At 5ºC + 95% RH	500 cm2	Zero perforation	4.60 yz	7.33 q:v	12.17 c:f	13.87 ab	14.33 a	10.46 a
		4 perforations	6.43 s:x	8.23 l:r	9.86 g:l	10.53 f:j	10.97 d:h	9.20 a
		8 perforations	2.20	3.46	7.96 o:t	8.13 m:s	9.00 i:q	6.15 bc
		Mean	4.41 JK'	6.34 G:I'	10.00 BC'	10.84 AB'	11.43 A'	8.60 A"
	600 cm2	Zero perforation	5.63 v:z	6.70 r:x	11.90 d:f	12.27 b:e	13.80 a:c	10.06 a
		4 perforations	2.567	3.30	9.73 g:n	9.96 g:k	10.63 e:i	7.24 b
		8 perforations	3.10	3.30	8.66 k:q	8.96 i:q	9.20 i:p	6.64 b
		Mean	3.76 KL'	4.43 JK'	10.10 BC'	10.40 A:C'	11.21 A'	7.98 A"
	Mean		4.08 G	5.38 F	10.05 B	10.62 AB	11.32 A	8.29 A

***Table 2:** Cont.*

Storage temperature	No. of perforations/package	Storage period (days)					Mean
		4	8	12	16	20	
At 0ºC + 95% RH	Zero perforation	5.03 m:o	6.91 i:k	8.21 gh	10.33 de	11.18 cd	8.33 B
	4 perforations	1.51 rs	5.56 l:n	6.45 j:l	7.36 h:j	7.98 g:i	5.77 C
	8 perforations	1.31 s	2.35 q:s	3.95 op	5.08 m:o	6.36 j:l	3.81 D
At 5ºC + 95% RH	Zero perforation	5.11 m:o	7.01 ij	12.03 bc	13.07 ab	14.07 a	10.26 A
	4 perforations	4.50 n:p	5.76 k:m	9.80 ef	10.25 de	10.80 de	8.22 B
	8 perforations	2.65 qr	3.38 pq	8.31 gh	8.55 gh	9.10 fg	6.40 C
Package area (cm2)	No. of perforations/package	Storage period (days)					Mean
		4	8	12	16	20	
500 cm2	Zero perforation	5.13 m:o	7.71 h:k	10.92 cd	12.65 ab	13.43 a	9.97 a
	4 perforations	3.86 p	7.13 j:l	8.71g:i	9.70 e:g	10.02 d:f	7.88 b
	8 perforations	1.71 r	3.26 pq	6.08 l:n	7.05 j:l	7.65 h:k	5.15 d
	Mean	3.57 FG	6.03 E	8.57 C	9.80 AB	10.37 A	7.67 A
600 cm2	Zero perforation	5.01 no	6.21 lm	9.33 fg	10.75 c:e	11.82 bc	8.62 b
	4 perforations	2.15 qr	4.20 op	7.53 i:k	7.91 h:j	8.76 gh	6.11 c
	8 perforations	2.25 qr	2.46 qr	6.18 l:n	6.58 kl	7.81 h:j	5.06 d
	Mean	3.13 G	4.29 F	7.68 D	8.41 CD	9.46 B	6.60 A
Mean	Zero perforation	5.07 K	6.96 GH	10.13 C	11.70 B	12.63 A	9.29 A
	4 perforations	3.00 L	5.66 JK	8.12 EF	8.80 DE	9.39 CD	7.00 B
	8 perforations	1.98 M	2.86 L	6.13 IJ	6.81 HI	7.73 FG	5.10 C
Mean		3.35 E	5.16 D	8.12 C	9.10 B	9.91 A	

Effect of different storage temperature, package areas and passive MAP treatments on general appearance score.

Variation in product quality and freshness was created by using different passive modified atmosphere packaging (MAP). Samples were stored in bags from LDPE film with different areas, perforation levels and stored at two storage temperatures (Table 3).

Overall visual quality is an important factor influencing the marketability of a food product. In this experiment, storage temperature significantly affected visual quality deterioration (Table 3) and visual quality decreased with increasing storage period. Throughout the whole 20-days storage period, MAP treatments stored at 0ºC were rated highest in overall quality, followed by MAP treatments stored at 5ºC, with the final score of 7. 80 and 6.02 on day 20th, respectively.

Package area didn't affect the quality of baby - pea shoots whereas the number of perforations/package did, bags with zero perforation and with 4 perforations had the highest quality and the lowest quality were recorded for bags with 8 perforations.

The interactions between storage temperature and package area showed that samples in both areas of bags and stored at 0ºC had the highest appearance compared with those stored at 5ºC. Also, samples stored at 0ºC in bags without perforations and with four perforation/package showed the higher visual quality compared with other treatments. The interactions between package area and number of perforations/package indicate that both areas of package with zero and four perforations had the highest quality compared with remain treatments.

The interactions between all treatments indicated that samples stored at 0ºC in bags of both areas and different perforations maintained its quality and kept its quality till the end of the storage period, whereas, samples stored at 5ºC in both package areas with different perforation levels maintained acceptable visual quality until day 8th, however, after day 8, yellowing was observed and all these samples experienced a sharp decline in overall quality which became unacceptable within 16 days of storage, indicating that temperature abuse is severely detrimental for the delicate baby - pea shoots.

Table 3: Effect of different storage temperature, package areas and passive MAP on General appearance (score) of baby - pea shoots (combined analysis of two seasons).

Storage temperature	Package area (cm2)	No. of perforations/package	Storage period (days) 4	8	12	16	20	Mean
At 0ºC + 95% RH	500 cm2	Zero perforation	9.00 a	9.00 a	9.00 a	7.00 cd	6.33 de	8.07 a
		4 perforations	9.00 a	9.00 a	7.00 cd	7.00 cd	7.00 cd	7.80 ab
		8 perforations	9.00 a	7.67 BC	7.00 CD	7.00 CD	7.00 CD	7.53 a:c
		Mean	9.00 A'	8.56 AB'	7.67 CD'	7.00 DE'	6.78 EF'	7.80 A"
	600 cm2	Zero perforation	9.00 a	8.33 ab	7.67 bc	7.00 cd	7.00 cd	7.80 ab
		4 perforations	9.00 a	9.00 a	9.00 a	7.00 cd	7.00 cd	8.20 a
		8 perforations	9.00 a	7.00 cd	7.00 cd	7.00 cd	7.00 cd	7.40 a;c
		Mean	9.00 A'	8.11 BC'	7.89 BC'	7.00 DE'	7.00 DE'	7.80 A"
	Mean		9.00 A	8.33 B	7.78 B	7.00 C	6.89C	7. 80 A
At 5ºC + 95% RH	500 cm2	Zero perforation	9.00 a	7.00 cd	7.00 cd	6.33 de	5.67 ef	7.00 bc
		4 perforations	9.00 a	9.00 a	7.00 cd	4.33 gh	3.67 hi	6.60 c
		8 perforations	9.00 a	7.67 bc	5.00 fg	3.00 ij	2.33 jk	5.40 d
		Mean	9.00 A'	7.89 BC'	6.33 EF'	4.56 G'	3.89 G'	6.33 AB"
	600 cm2	Zero perforation	9.00 a	7.67 bc	7.67 bc	5.00 fg	4.33 gh	6.73 c
		4 perforations	9.00 a	8.33 ab	5.67 ef	2.33 jk	2.33 jk	5.53 d
		8 perforations	9.00 a	7.67 bc	5.00 fg	1.67 kl	1.00 l	4.87 d
		Mean	9.00 A'	7.89 BC'	6.11 F'	3.00 H'	2.56 H'	5.71 B"
	Mean		9.00 A	7.89 B	6.22 D	3.78 E	3.22 E	6.02 B

***Table 3:** Cont.*

Storage temperature	No. of perforations/package	Storage period (days) 4	8	12	16	20	Mean
At 0ºC + 95% RH	Zero perforation	9.00 a	8.67 ab	8.33 a:c	7.00 e:g	6.67 fg	7.93 A
	4 perforations	9.00 a	9.00 a	8.00 b:d	7.00 e:g	7.00 e:g	8.00 A
	8 perforations	9.00 a	7.33 d:f	7.00 e:g	7.00 e:g	7.00 e:g	7.47 AB
At 5ºC + 95% RH	Zero perforation	9.00 a	7.33 d:f	7.33 d:f	5.67 hi	5.00 i	6.87 B
	4 perforations	9.00 a	8.67 ab	6.33 gh	3.33 j	3.00 jk	6.07 C
	8 perforations	9.00 a	7.67 c:e	5.00 i	2.33 kl	1.67 l	5.13 D
Package area (cm2)	No. of perforations/package	Storage period (days) 4	8	12	16	20	Mean
500 cm2	Zero perforation	9.00 a	8.00 bc	8.00 bc	6.67 ef	6.00 fg	7.53 a
	4 perforations	9.00 a	9.00 a	7.00 de	5.67 gh	5.33 g:i	7.20 a
	8 perforations	9.00 a	7.67 cd	6.00 fg	5.00 h:j	4.67 i:k	6.47 bc
	Mean	9.00 A	8.22 B	7.00 C	5.78 D	5.33 DE	7.07 A
600 cm2	Zero perforation	9.00 a	8.00 bc	7.67 cd	6.00 fg	5.67 gh	7.27 a
	4 perforations	9.00 a	8.67 ab	7.33 c:e	4.67 i:k	4.67 i:k	6.87 ab
	8 perforations	9.00 a	7.33 c:e	6.00 fg	4.33 jk	4.00 k	6.13 c
	Mean	9.00 A	8.00 B	7.00 C	5.00 E	4.78 E	6.76 A
Mean	Zero perforation	9.00 A	8.00 B	7.83 B	6.33 D	5.83 D	7.40 A
	4 perforations	9.00 A	8.83 A	7.17 C	5.17 E	5.00 E	7.03 A
	8 perforations	9.00 A	7.50 BC	6.00 D	4.67 EF	4.33 F	6.30 B
		9.00 A	8.11 B	7.00 C	5.39 D	5.06 D	

Effect of storage temperature, package areas and passive MAP treatments on decay of baby - pea shoots.

Data in Table (4) illustrated the effect of modified atmosphere packaging (MAP) treatments on decay score of baby - pea shoots. The higher the storage temperature was, the higher the intensity of decay was detected. Also, decay increased with increasing storage period and no decay was detected on baby - pea shoots before day 8 for all treatments. Samples stored at 0ºC exhibited slight decay and had the lowest decay score (1.43) whereas those stored at 5ºC exhibited moderate decay score (2.45). Package area didn't affect decay, whereas number of perforations/package affected decay of samples. Decay increased with the decreased of number of perforations/package. Package with zero perforation had the highest decay score (2.25) and lowest score were recorded with samples stored in bags with 8 perforations.

The interaction between storage temperature and package area showed that samples stored at 0ºC for both package areas had the lowest decay score values compared with those stored at 5ºC. Also, the interaction between storage temperature and number of perforations/package had the same trend whereas the lowest decay score values recorded for samples stored at 0ºC for different number of perforations.

On day 12, all MAP treatments stored at 5ºC displayed slight to moderate decay, whereas, decay noticed in MAP treatments stored at 0ºC after 16 days of storage. At the end of storage period, only slight to moderate decay were detected in the MAP stored at 0ºC and moderate to severe in MAP treatments stored at 5ºC.

Table 4: Effect of different storage temperature, package areas and passive MAP on Decay (score) of baby - pea shoots (combined analysis of two seasons).

Storage temperature	Package area (cm2)	No. of perforations/package	Storage period (days)					Mean
			4	8	12	16	20	
At 0ºC + 95% RH	500 cm2	Zero perforation	1.00 i	1.00 i	1.00 i	1.00 I	2.33 e:g	1.27 e
		4 perforations	1.00 i	1.00 i	1.00 i	2.00 f:h	2.67 d:f	1.53 e
		8 perforations	1.00 i	1.00 i	1.33HI	2.00 f:h	2.67 d:f	1.60 de
		Mean	1.00 E'	1.00 E'	1.11 E'	1.67 D'	2.56 C'	1.47 B"
	600 cm2	Zero perforation	1.00 i	1.00 i	1.00 i	1.33 hi	2.33 e:g	1.33 e
		4 perforations	1.00 i	1.00 i	1.00 i	1.67 g:i	2.00 f:h	1.33 e
		8 perforations	1.00 i	1.00 i	1.00 i	2.00 f:h	2.67 d:f	1.53 e
		Mean	1.00 E'	1.00 E'	1.00 E'	1.67 D'	2.33 C'	1.40 B"
	Mean		1.00 E	1.00 E	1.06 E	1.67 D	2.44 C	1.43 B
At 5ºC + 95% RH	500 cm2	Zero perforation	1.00 i	1.00 i	1.67 g:i	2.33 e:g	3.00 c:e	1.80 c:e
		4 perforations	1.00 i	1.00 i	1.67 g:i	3.33 cd	4.33 ab	2.27 bc
		8 perforations	1.00 i	1.00 i	3.00 c:e	4.33 ab	5.00 a	2.87 a
		Mean	1.00 I'	1.00 I'	2.11 CD'	3.33 B'	4.11A'	2.31 AB"
	600 cm2	Zero perforation	1.00 i	1.00 i	1.67 g:i	3.33 cd	3.67 bc	2.13 b:d
		4 perforations	1.00 i	1.00 i	2.67 d:f	4.33 ab	4.33 ab	2.67 ab
		8 perforations	1.00 i	1.00 i	3.00 c:e	5.00 a	5.00 a	3.00 a
		Mean	1.00 I'	1.00 I'	2.44 C'	4.22 A'	4.33 A'	2.60 A"
	Mean		1.00 I	1.00 I	2.28 C	3.78 B	4.22 A	2.45 A

Table 4: *Cont.*

Storage temperature	No. of perforations/package	Storage period (days)					Mean
		4	8	12	16	20	
At 0ºC + 95% RH	Zero perforation	1.00 j	1.00 j	1.00 j	1.17 j	2.33 f:h	1.30 D
	4 perforations	1.00 j	1.00 j	1.00 j	1.83 hi	2.33 f:h	1.43 D
	8 perforations	1.00 j	1.00 j	1.17 j	2.00 hi	2.67 e:g	1.57 CD
At 5ºC + 95% RH	Zero perforation	1.00 j	1.00 j	1.67 i	2.83 d:f	3.33 d	1.97 C
	4 perforations	1.00 j	1.00 j	2.17 g:i	3.83 c	4.33 b	2.47 B
	8 perforations	1.00 j	1.00 j	3.00 de	4.67 ab	5.00 a	2.93 A
Package area (cm2)	No. of perforations/package	Storage period (days)					Mean
		4	8	12	16	20	
500 cm2	Zero perforation	1.00 h	1.00 h	1.33 gh	1.67 fg	2.67 cd	1.53 c
	4 perforations	1.00 h	1.00 h	1.33 gh	2.67 cd	3.50 ab	1.90 a:c
	8 perforations	1.00 h	1.00 h	2.17 d:f	3.17 bc	3.83 a	2.23 a
	Mean	1.00 E	1.00 E	1.61 D	2.50 C	3.33 A	1.89 A
600 cm2	Zero perforation	1.00 h	1.00 h	1.33 gh	2.33 de	3.00 bc	1.73 bc
	4 perforations	1.00 h	1.00 h	1.83 e:g	3.00 bc	3.00 bc	2.00 ab
	8 perforations	1.00 h	1.00 h	2.00 ef	3.50 ab	3.83 a	2.27 a
	Mean	1.00 E	1.00 E	1.72 D	2.94 B	3.33 A	2.00 A
Mean	Zero perforation	1.00 F	1.00 F	1.33 EF	2.00 D	2.83 C	1.63 C
	4 perforations	1.00 F	1.00 F	1.58 E	2.83 C	3.33 B	1.95 B
	8 perforations	1.00 F	1.00 F	2.08 D	3.33 B	3.83 A	2.25 A
Mean		1.00 D	1.00 D	1.67 C	2.72 B	3.33 A	

5= severe; 4= moderately severe; 3= moderate; 2= slight and 1= none

Effect of different storage temperature, package areas and passive MAP treatments on off-odor (score).

Data in Table (5) showed the effect of different MAP treatments on off odor. Off odor not affected by storage temperature, package area, number of perforations/package and increased with prolonged storage period.

No off-odor was detected on baby - pea shoots before day 4 for all treatments. On day 12, all the treatments displayed slight to moderate off-odor. At the end of 20-day storage, slight and moderate off odors were detected in the samples stored at 0ºC and moderate off-odor was detected in 5ºC treatments.

The interactions between storage temperature, package area and number of perforations/package showed significant effect where the lowest value of off odor detected in samples stored at 0ºC in package area 600 cm^2 for the three perforation levels, and the highest value of off odor where noticed in all samples stored at 5ºC.Also, the interactions between storage temperature, package area and storage period showed significant effect where differences between treatments noticed at 8 day of storage

The development of off-odors had a positive correlation with the decrease of O_2 and the increase of electrolyte leakage, suggesting that tissue senescence and deterioration resulted in cell membrane damage and undesirable fermentative volatiles, such as ethanol and acetaldehyde as reported before by Kim *et al*., 2005.

Table 5: Effect of different storage temperature, package areas and passive MAP on Off-odor (score) of baby - pea shoots (combined analysis of two seasons).

Storage temperature	Package area (cm2)	No. of perforations/package	Storage period (days)					Mean
			4	8	12	16	20	
At 0ºC + 95% RH	500 cm2	Zero perforation	1.00 i	1.00 i	2.00 f:h	2.67 d:f	3.33 b:d	2.00 bc
		4 perforations	1.00 i	1.00 i	2.00 f:h	3.00 c:e	3.33 b:d	2.07 bc
		8 perforations	1.00 i	1.00 i	2.33 e:g	2.67 d:f	3.33 b:d	2.07 bc
		Mean	1.00 E'	1.00 E'	2.11 D'	2.78 C'	3.33 B'	2.04 A"
	600 cm2	Zero perforation	1.00 i	1.33 hi	2.00 f:h	2.00 f:h	2.67 d:f	1.80 c
		4 perforations	1.00 i	2.00 f:h	2.00 f:h	2.33 e:g	3.00 c:e	2.07 bc
		8 perforations	1.00 i	1.67 g:i	2.00 f:h	2.00 f:h	2.33 e:g	1.80 c
		Mean	1.00 E'	1.67 D'	2.00 D'	2.11 D'	2.67 C'	1.89 A"
	Mean		1.00 F	1.33 F	2.06 E	2.44 D	3.00 BC	1.97 A
At 5ºC + 95% RH	500 cm2	Zero perforation	1.00 i	2.00 f:h	2.00 f:h	2.67 d:f	3.67 a:c	2.27 a:c
		4 perforations	1.00 i	2.00 f:h	3.00 c:e	3.33 b:d	3.33 b:d	2.53 ab
		8 perforations	1.00 i	2.00 f:h	3.00 c:e	2.33 e:g	3.33 b:d	2.33 a:c
		Mean	1.00 E'	2.00 D'	2.67 C'	2.78 C'	3.44 B'	2.38 A"
	600 cm2	Zero perforation	1.00 i	2.00 f:h	2.33 e:g	3.33 b:d	4.00 ab	2.53 ab
		4 perforations	1.00 i	2.00 f:h	3.00 c:e	3.67 a:c	4.33 a	2.80 a
		8 perforations	1.00 i	2.00 f:h	2.67 d:f	3.33 b:d	4.00 ab	2.60 ab
		Mean	1. 00 E	2.00 D'	2.67 C'	3.44 B'	4.11 A'	2.64 A"
	Mean		1.00 F	2.00 E	2.67 CD	3.11 B	3.78 A	2.51 A

5= severe; 4= moderately severe; 3= moderate; 2= slight and 1= none

Table 5: *Cont.*

Storage temperature	No. of perforations/package	Storage period (days)					Mean
		4	8	12	16	20	
At 0ºC + 95% RH	Zero perforation	1.00 i	1.17 i	2.00 gh	2.33 e:g	3.00 cd	1.90 C
	4 perforations	1.00 i	1.50 hI	2.00 gh	2.67 d:f	3.17 b:d	2.07 BC
	8 perforations	1.00 i	1.33 i	2.17 fg	2.33 e:g	2.83 de	1.93 C
At 5ºC + 95% RH	Zero perforation	1.00 i	2.00 gh	2.17 fg	3.00 cd	3.83 a	2.40 AB
	4 perforations	1.00 i	2.00 gh	3.00 cd	3.50 a:c	3.83 a	2.67 A
	8 perforations	1.00 i	2.00 gh	2.83 de	2.83 de	3.67 ab	2.47 AB
Package area (cm2)	No. of perforations/package	Storage period (days)					Mean
		4	8	12	16	20	
500 cm2	Zero perforation	1.00 j	1.50 ij	2.00 f:i	2.67 c:e	3.50 ab	2.13 a
	4 perforations	1.00 j	1.50 ij	2.50 d:f	3.17 a:c	3.33 ab	2.30 a
	8 perforations	1.00 j	1.50 ij	2.67 c:e	2.50 d:f	3.33 ab	2.20 a
	Mean	1.00 E	1.50 D	2.39 C	2.78 B	3.39 A	2.21 A
600 cm2	Zero perforation	1.00 j	1.67 hi	2.17 e:h	2.67 c:e	3.33 ab	2.17 a
	4 perforations	1.00 j	2.00 f:i	2.50 d:f	3.00 b:d	3.67 a	2.43 a
	8 perforations	1.00 j	1.83 g:i	2.33 e:g	2.67 c:e	3.17 a:c	2.20 a
	Mean	1.00 E	1.83 D	2.33 C	2.78 B	3.39 A	2.27 A
Mean	Zero perforation	1.00 F	1.58 E	2.08 D	2.67 C	3.47 AB	2.15 A
	4 perforations	1.00 F	1.75 DE	2.50 C	3.08 B	3.50 A	2.37 A
	8 perforations	1.00 F	1.67 E	2.50 C	2.58 C	3.25 AB	2.20 A
Mean		1.00 E	1.67 D	2.36 C	2.78 B	3.39 A	

5= severe; 4= moderately severe; 3= moderate; 2= slight and 1= none

Conclusion

The quality and shelf life of baby - pea shoot as impacted by four major postharvest treatment factors, i.e. storage temperature, package area, number of perforations/package, and storage period, were evaluated in this study. Storage temperature had a significant impact on package atmosphere, product visual quality, decay and off odor score.

A temperature of 0ºC was rated as the best storage temperature for baby - pea shoots treatment. Samples stored at 0ºC maintained the highest overall visual quality with minimum decay and off-odor development, whereas those stored at 5ºC lost quality more rapidly. Package area didn't have significant effect on the quality and shelf life of the product, probably because levels of oxygen and carbon dioxide in both package areas were close. Number of perforations/package significantly affected headspace gas composition during storage; consequently appearance and decay of the product, however, it did not have a significant effect on off odor.

It could be concluded that, baby pea shoot packaged in LDPE film bags stored at 0ºC in both package areas (500 cm^2 and 600 cm^2) without perforations or with 4 and 8 perforations maintained good quality and shelf life throughout 16 days. baby - pea shoots stored at 5ºC in both package areas (500 cm^2 and 600 cm^2) without perforations maintained good quality and shelf life throughout 12 days and 8 days for packages with 4 and 8 perforations/package.

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