Effect of cultivar, packaging treatments and temperature on post-harvest quality of okra

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ABSTRACT

Okra is one of the most popular vegetable crops in Sudan. The introduced cultivars such as Pusa Swani and Clemson Spineless have smooth pods and more adapted to the winter conditions of central Sudan. However, the local cultivar, Khartoumia, has hairy pods and not acceptable in international markets. Okra pods are highly perishable and subject to shriveling especially under the hot arid conditions of central Sudan. Therefore, the objective of this study was to determine the effect of packaging and temperature on the shelf life of okra pods of three introduced cultivars. Treatments consisted of three okra cultivars, namely, Clemson Spineless, Pusa Swani and Mahyco (hybrid); packaging treatments consisted of packing okra pods in cartons lined with intact polyethylene film, perforated polyethylene film or in cartons only and storage temperatures were 14^0C and 32^0C. Results showed that pods of the cultivar Mahyco had the lowest weight loss, retained good colour and had the least decay and rot. Packaging of okra pods in intact or perforated polyethylene film and storing at 14^0C reduced weight loss and resulted in the best pod colour compared to the control. Packaging in perforated polyethylene film and storing at 14^0C resulted in the lowest incidence of decay and rot and best overall quality of pods. It is recommended to package okra pods in perforated polyethylene film and ship them to markets at 14^0C.

INTRODUCTION

Okra is a highly perishable vegetable crop with a high rate of respiration and a short shelf life. It is liable to water loss which results in shriveling and reduced quality especially under hot arid conditions and low relative humidity (Thompson, 1996).

Temperature management is one of the most effective tools for extending the shelf life of okra. Fresh okra can be stored satisfactorily for 7-10 days at 10^0C (Kemble *et al.*, 1995). At temperatures below 8^0C, okra is subject to chilling injury which is manifested by surface discolouration, pitting and decay (Perkins-Veazie and Collins, 1992; Cantwell and Suslow, 2002). Nevertheless, exposure of okra pods to high temperatures accelerates the rate of respiration, reduces O_2, increases CO_2 levels and encourages pathogen growth (Sargent *et al.*, 2000; Cantwell and Trevor, 2002).

The technique of polymeric film packaging has been used to modify O_2 and CO_2 concentrations within the package, improve water retention and reduce weight loss (Elkashif *et al*., 2005). However, the build up of high relative humidity inside the package may result in water condensation which promotes decay and rot in okra pods (Medlicott, 1990). In a similar study, bell peppers which were stored in perforated packages had a lower decay incidence than those stored in non-perforated packages (Yehoshua *et al.,* 1998). Polyethylene film packaging has been found to extend the shelf life of bananas (Mahmoud and Elkashif, 2003; Elkashif *et al.*, 2005; Elamin and Abu-Goukh, 2009), mangoes (Elkashif *et al.*, 2003) and parsley (Heyes, 2004).

There is a lack of information on the optimum post-harvest handling practices of fresh okra pods. Therefore, the objective of this study was to determine the best post-harvest packaging treatments and temperature that would result in the best quality and the longest shelf life of fresh okra pods.

MATERIALS AND METHODS

Experimental site

Experiments were conducted at the Research Farm of the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan, during seasons 2007/08 and 2008/09. It is located at latitude 14^0 6'N, longitude 33^0 38'E and altitude 406.9 masl. The area of the experimental site falls within the dry zone with a short rainy season that extends from June to September where the average annual rainfall is about 300 mm/year. The mean relative humidity is 39% and the annual evaporation is 2500 mm/year (Adam, 1998).

Land preparation, planting and experimental set up

The experimental area was ploughed, harrowed , leveled and ridged at a spacing of 80 cm. Three cultivars, namely, Clemson Spineless, Pusa Swani and Mahyco (hybrid) were used in this study. Seeds were sown during the second week of February at a spacing of 20 cm. Three seeds were sown per hole and plants were thinned to two 15 days after planting. Manual weeding, followed by raising-up of the ridges were carried out regularly at 15 days interval. Plants were irrigated at 8 to 10 days interval depending on weather conditions. Insects and disease control were done whenever necessary. Plot size was 3.2 x 4 m. The experimental design was a randomized complete block with three replicates.

Post-harvest treatments

Tender okra pods (3 – 4 cm) from both seasons were harvested after 50 days from sowing and subjected to three packaging treatments and two storage temperatures. Packaging treatments consisted of packing okra pods in cartons only, cartons lined with perforated polyethylene film and cartons lined with intact polyethylene film. Storage temperatures were 14^0C and 32^0C. Treatments were arranged in a completely randomized design with two replicates. The post-harvest parameters determined were pod weight loss, colour change, pathogen infection and overall quality. Okra pods were initially weighed and then weighed daily till they showed obvious signs of shriveling.

Weight loss (%) = (Wi–Wt)/Wi x 100, where: Wi =Initial weight

Wt = weight at designated time.

Pod colour was rated daily according to the following scale:

1- Dark green; 2, green; 3, yellowish green; 4, more yellow than green; 5, yellow.

Rotting was also rated on a scale of 1-3:

1. No rotting.
2. Moderate rotting.
3. Severe rotting.

Overall quality was rated on a scale of 1-5, as follows:

1. High.
2. Good.
3. Fair.
4. Poor.
5. Very poor.

Data were subjected to analysis of variance. Means were separated using Duncan's Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Okra pods, being immature fruits, are highly perishable due to their high rates of water loss and respiration. Post-harvest parameters of okra pods were taken for both seasons. Since the experiment was conducted under controlled conditions, there were no significant differences between seasons. So the results presented in this paper were the average of two seasons.

Effects of packaging treatments and storage temperature on the following post-harvest parameters:

1. Weight loss

The main effects of cultivar and packaging treatments on percentage weight loss of pods stored at 14^0C and 32^0C were significant (Tables 1 and 2). Pusa Swani showed the highest weight loss while Mahyco exhibited the lowest weight loss at both temperatures. This was probably because Pusa Swani cultivar had a higher surface area than Mahyco, which was smooth. Packaging okra pods in non-perforated films resulted in the lowest weight loss at both temperatures as compared to the other treatments (Tables 1 and 2). Generally, weight loss was higher at 32^0C compared to 14^0C.

Table 1. Effect of okra cultivar and packaging treatments on percentage weight loss of pods stored at 14^0 C.

Cultivar	Days of storage					
	2	3	4	5	6	7
Pusa Swani	0.3 a	2.33 a	3.79 a	5.79	6.79	9.08 a
Clemson	0.1 b	1.93 b	3.69 a	5.12	6.27	8.24 b
Mahyco	0.0 c	1.88 b	3.07 b	5.24	6.20	8.23 b
Sig. level	**	*	**	NS	NS	*
Packaging treatments						
Non-perforated	0.04 b	0.83 c	2.24 b	3.10 c	3.85 c	5.39 c
Perforated	0.07 b	1.44 b	2.74 b	4.99 b	5.38 b	8.55 b
Control	0.27 a	3.88 a	5.57 a	8.06 a	10.03 a	11.62 a
Sig. level	*	**	**	***	***	***

Means within columns followed by the same letter(s) are not significantly different at $P \leq 0.05$ level according to Duncan's Multiple Range Test.
*,**,*** and NS indicate significance at $P \leq 0.05$, 0.01 and 0.001 and not significant, respectively.

Non-perforated films created a micro-environment of high relative humidity which greatly reduced water loss from the pods. At both temperatures (14^0C and 32^0C), okra pods stored in perforated films or unpackaged were severely shriveled and turned unacceptable at the end of the storage period (7 days). The extent of shriveling was greater at 32^0C as compared to 14^0C. Takele *et al.* (1996) reported that okra pods should be stored at 7^0C and a relative humidity of 90% to 95%. However, at such a temperature, chilling injury of okra pods may be a problem. Okra pods are very sensitive to weight loss and a moisture loss of 3% will cause okra to appear wilted (Kemble *et al.*, 1995). They also reported that the pods were nearly shriveled after four days of storage at a warm temperature and low relative humidity. Packaging of pods in intact polyethylene film resulted in a high relative humidity inside the package and hence reduced weight loss compared with perforated and control treatments. Elkashif *et al.* (2003; 2005) and Elamin and Abu-Goukh (2009) reported similar findings with mangoes and bananas .Cantwell and Suslow (2002) reported that weight loss of okra pods varies with cultivar, stage of pod maturity and environmental conditions. Weight loss of okra pods resulted in pod dehydration, toughening and loss of fresh appearance. Interaction effects of packaging treatments and temperature on weight loss were not significant.

Table 2. Effect of okra cultivar and packaging treatments on percentage weight loss of pods stored at 32^0 C.

Cultivar	Days of storage			
	2	3	4	5
Pusa Swani	2.12 a	6.19 a	9.19 a	12.45 a
Clemson	1.81 ab	5.32 b	8.97 b	11.96 ab
Mahyco	1.60 b	5.22 b	8.79 b	11.72 b
Sig. level	*	**	*	**
Packaging treatments				
Non-perforated	1.58 b	4.10 b	7.48 c	9.07 c
Perforated	1.79 b	4.49 b	8.01 b	12.60 b
Control	2.15 a	8.13 a	11.47 a	14.46 a
Sig. level	**	**	**	**

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.
* and ** indicate significance at P≤0.05 and 0.01, respectively.

2. Colour of pods

The effects of okra cultivar and packaging treatments on colour of pods stored at 14^0C and 32^0C were significant (Tables 3 and 4). Pod colour changed from bright green to greenish yellow after six days in storage for all tested cultivars. However, Mahyco cultivar was the best in retaining its original green colour as compared to the other two cultivars at both temperatures. Green colour retention of the pods was better at 14^0C than at 32^0C for all cultivars. Similarly, Kemble *et al.* (1995) reported that packaging treatments had significant effects on okra pod colour. The best results were obtained with the non-perforated film at both temperatures and the worst results were obtained with the control treatment. The retention of the green colour of pods packed in non-perforated film was probably due to the high build up of CO_2 inside the package which antagonized ethylene action and hence prevented the degradation of chlorophyll usually associated with exposure to ethylene. Also, the high moisture loss encountered with the pods packed in perforated film and in cartons without film (control) might have probably accelerated the loss of the green colour. Interaction effects of packaging treatments and temperature on colour of pods were not significant

Table 3. Effect of okra cultivar and packaging treatments on the color scale+ of pods stored at 14^0 C.

Cultivar	Days of storage					
	1	2	3	4	5	6
Pusa Swani	1.00	1.42 a	1.67 a	1.92 a	2.33 a	2.50 ab
Clemson	1.00	1.50 a	1.67 a	2.00 a	2.42 a	2.58 a
Mahyco	1.00	1.25 b	1.50 b	1.83 b	2.08 b	2.42 b
Sig. level	NS	*	*	**	*	*
Packaging treatments						
Non-perforated	1.00	1.25 b	1.50 b	1.67 b	2.17 b	2.33 b
Perforated	1.00	1.42 a	1.58 b	1.92 b	2.17 b	2.50 ab
Control	1.00	1.50 a	1.75 a	2.17 a	2.50 a	2.67 a
Sig. level	NS	*	*	**	*	*

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.
* ,** and NS indicate significance at P≤ 0.05, 0.01 and not significant, respectively.
+The color scale was: 1, dark green; 2, green; 3, yellowish green; 4, more yellow than green; 5, yellow.

Table 4. Effect of okra cultivar and packaging treatments on the color scale+ of pods stored at 32^0 C.

Cultivar	Days of storage			
	1	2	3	4
Pusa Swani	1.00	1.83 a	2.25 a	2.50 a
Clemson	1.00	1.83 a	2.17 a	2.58 a
Mahyco	1.00	1.67 b	1.92 b	2.33 b
Sig. level	NS	*	*	*
Packaging treatments				
Non-perforated	1.00	1.67 c	1.92 c	2.33 b
Perforated	1.00	1.75 b	2.17 b	2.42 b
Control	1.00	1.92 a	2.25 a	2.67 a
Sig. level	NS	*	*	*

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.
* and NS indicate significance at P≤0.05 and not significant, respectively.

+The color scale was: 1, dark green; 2, green; 3, yellowish green; 4, more yellow than green; 5, yellow.

3. Rotting

The effects of okra cultivar and packaging treatments on rotting of okra pods stored at 14^0C and 32^0C were significant (Tables 5 and 6). Generally, the incidence of rotting increased as the storage period progressed. Mahyco cultivar showed the least rotting as compared to the other two cultivars at both temperatures. Packaging treatments had significant effects on rotting at both temperatures. The non-perforated polymeric film resulted in the highest incidence of rotting at both temperatures as compared to the other two packaging treatments. However, the control treatment (unwrapped) resulted in the lowest incidence of rotting at both temperatures. The high incidence of rotting encountered with the non-perforated film wrap was most probably due to the high relative humidity inside the package which encouraged the growth of micro-organisms, thus resulting in the rotting of pods. On the contrary, pods packed in cartons without wraps (control) did not show remarkable signs of rotting because they were exposed to the open air which had low relative humidity and hence did not encourage the growth of pathogenic micro-organisms. Perkins-Veazie and Collins (1992) and Yehoshua *et al*. (1998) reported similar results.

Table 5. Effect of okra cultivar and packaging treatments on the rotting scale+ of pods stored at 14^0 C.

Cultivar	Days of storage					
	1	2	3	4	5	6
Pusa Swani	1.00	1.33	1.58	1.75 a	2.25 a	2.50 b
Clemson	1.00	1.33	1.50	1.67 b	2.17 b	2.67 a
Mahyco	1.00	1.25	1.42	1.67 b	1.83 c	2.25 c
Sig. level	NS	NS	NS	*	*	*
Packaging treatments						
Non-perforated	1.00	1.33 b	1.50 b	1.75 a	2.17 a	2.50 a
Perforated	1.00	1.17 c	1.33 c	1.58 b	1.83 b	2.25 b
Control	1.00	1.42 a	1.67 a	.55 b	1.80 b	2.17 b
Sig. level	NS	*	*	*	*	*

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.

* and NS indicate significance at P≤0.05 and not significant, respectively.

+The rotting scale was:1 = No rotting , 2= Moderate rotting , 3 =Severe rotting.

Table 6. Effect of okra cultivar and packaging treatments on the rotting scale+ of pods stored at 32^0 C.

Cultivar	Days of storage			
	1	2	3	4
Pusa Swani	1.00	1.50 b	2.25 a	2.67 a
Clemson	1.00	1.75 a	2.25 a	2.50 b
Mahyco	1.00	1.58 b	2.00 b	2.42 c
Sig. level	NS	*	*	*
Packaging treatments				
Non-perforated	1.00	1.58	2.17 a	2.58 a
Perforated	1.00	1.58	1.92 b	2.33 b
Control	1.00	1.67	1.83 c	2.17 b
Sig. level	NS	NS	*	*

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.
Sig. = Significant.
* and NS indicate significance at P≤0.05 and not significant, respectively.
+The rotting scale was:1 = No rotting, 2= Moderate rotting, 3 =Severe rotting.

Generally, the extent of rotting was more severe at 32^{0}C than at 14^{0}C and hence the storage period was two days shorter at 32^{0}C. Cantwell and Trevor (2002) reported that pathogenic infections of okra pods were caused by *Rhizoctonia* fungi as well as bacterial rots caused by *pseudomonas* species. Interaction effects of packaging treatments and temperature on rotting of pods were not significant.

4. Overall quality of pods

The effects of okra cultivar and packaging treatments on the overall quality of okra pods held at 14^{0}C and 32^{0}C were significant (Tables 7 and 8). The post-harvest quality of okra pods decreased with storage duration. Mahyco cultivar significantly resulted in the best quality under both temperatures compared to Pusa Swani and Clemson. The pods of Mahyco cultivar were found to be suitable for export till the fourth day of storage when they were stored at 14^{0}C. However, okra pods stored at 32^{0}C were of poor quality in the second day of storage.

Table 7. Effect of okra cultivar and packaging treatments on the scale+ of overall quality of pods stored at 14^0 C.

	Days of storage					
Cultivar	1	2	3	4	5	6
Pusa Swani	1.5	1.83 b	2.25 b	3.58 a	4.17 a	4.58 a
Clemson	1.58	1.92 a	2.33 a	2.83 b	3.25 b	3.58 b
Mahyco	1.5	1.75 c	2.08 c	2.75 c	3.08 c	3.33 c
Sig. level	NS	*	*	*	**	**
Packaging treatments						
Non-perforated	1.5	1.75 b	2.17 b	3.08 b	3.50 b	3.83 b
Perforated	1.25	1.50 b	1.92 c	2.83 c	3.08 c	3.42 c
Control	1.83	2.25 a	2.58 a	3.25 a	3.92 a	4.25 a
Sig. level	NS	**	*	*	*	*

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.

*,** and NS indicate significance at P≤0.05, 0.01 and not significant, respectively.
+The scale of overall quality was: 1 = High. 2= Good. 3= Fair. 4= Poor. 5= Very poor.

There were highly significant differences between the packaging treatments. Okra pods packaged in perforated film showed good quality at both temperatures while those packaged in non- perforated film or control had fair and poor quality, respectively. Okra pods held at 32^0C deteriorated very rapidly compared to those held at 14^0C.

Table 8. Effect of okra cultivar and packaging treatments on the scale+ of overall quality of pods stored at 32^0 C.

Cultivar	Days of storage			
	1	2	3	4
Pusa Swani	1.92	3.08 a	4.17 a	4.58 b
Clemson	1.92	2.92 b	3.75 b	4.75 a
Mahyco	1.67	2.58 c	3.50 c	4.08 c
Sig. level	NS	*	*	*
Packaging treatments				
Non-perforated	1.92 b	3.17 b	3.75 b	4.33 b
Perforated	1.42 b	2.17 c	3.42 c	4.42 b
Control	2.17 a	3.25 a	4.25 a	4.67 a
Sig. level	**	*	*	*

Means within columns followed by the same letter(s) are not significantly different at P≤0.05 level according to Duncan's Multiple Range Test.
*,** and NS indicate significance at P≤0.05, 0.01 and not significant, respectively.
+The scale of overall quality was: 1 = High. 2= Good. 3= Fair. 4= Poor. 5= Very poor.

Quality losses in okra were also reported to be associated with mechanical damage, water loss, chilling injury and decay (Kemble *et al.*, 1995). Cantwell and Suslow (2002) showed that good quality of okra could be maintained up to 10 days at 10^0C. However, if okra pods were stored at higher temperatures, they lose quality rapidly due to dehydration, yellowing and decay because the high temperature accelerated the rate of water loss and the pods become shriveled in the second day and were rendered unmarketable. Interaction effects of packaging treatments and temperature on the overall quality of pods were not significant.

In conclusion, the export package for okra is to grow Mahyco cultivar, pack the pods in perforated polyethylene film and ship them to international markets at 10 C^0-14 C^0 .

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تاثير الصنف و معاملات التعبئة و درجة الحرارة على جودة البامية بعد الحصاد

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الخلاصة

تعتبر البامية من محاصيل الخضر المرغوبة في السودان. الأصناف المستوردة مثل بوزا سواني، و كلمسون لديها قرون ملساء و متأقلمة مع ظروف الشتاء في أواسط السودان. أما الصنف المحلي؛ خرطومية، فهو يتمتع بقرون تكسوها الشعيرات و بالتالي فهو غير مرغوب في الأسواق العالمية. قرون البامية سريعة التلف و تتعرض للكرمشة في درجات الحرارة العالية و الرطوبة النسبية المنخفضة. الهدف من هذه الدراسة هو معرفة تأثير طرق التعبئة و درجة الحرارة على جودة البامية بعد الحصاد لثلاثة أصناف من البامية و هي: كلمسون، و بوزا سواني، و مهايكو (هجين). معاملات التعبئة كانت تعبئة البامية في كراتين مبطنة بأكياس بوليثين غير مخرمة و مبطنة بأكياس مخرمة و في كراتين فقط بدون أكياس (شاهد). درجات حرارة التخزين كانت 14^0 م و 32^0 م. أوضحت النتائج أن قرون البامية من الصنف مهايكو أعطت أدنى معدل لفقدان الوزن و التعفن و كانت ذات لون جيد. تعبئة قرون البامية في أكياس البوليثين المخرمة أو غير المخرمة و تخزينها في درجة حرارة 14^0م أدى إلى تقليل فقدان الوزن و أفضل لون للقرون بالمقارنة مع الشاهد. تعبئة القرون في أكياس البوليثين المخرمة و تخزينها في درجة حرارة 14^0م أدى إلى أدنى معدل للتعفن و أفضل جودة للقرون بالمقارنة مع درجة الحرارة 32^0م. لذلك نوصي بتعبئة قرون البامية في أكياس البوليثين المخرمة اوغير المخرمة و ترحيلها للأسواق في درجة حرارة 10^0 م - 14^0م.