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ORIGINAL ARTICLE

Storage quality of shelled green peas under modified atmosphere packaging at different storage conditions

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Abstract Storage quality of shelled green peas (*Pisum sativum* var. *sativum* L) was investigated under modified atmosphere packaging (MAP: perforated and non perforated) compared to unsealed samples, respectively, at T1 (4 ± 1 °C and 94 ± 2 % RH) and T2 (10 ± 1 °C and 90 ± 2 % RH) for each sample and during period of storage (8, 16 and 24 days). Modified atmosphere (MA) was created using low density polyethylene (LDPE) film packages having 107 μm of film thickness and package size of 0.022 m^2. Quality parameters viz., weight loss (WL), total phenolic content (TPC), instrumental colour, ascorbic acid (AA) and sensory characteristics were evaluated during storage period. Weight loss was in the range of 0.18 to 3.54 (zero perforation at T1), 0.21 to 6.48(unsealed samples at T2) and 0.31 to 9.64 % (zero perforation at T1) after 8, 16 and 24 days of storage, respectively. Total phenolic content significantly increased to 102.47–161.54 mg/100 g from an initial value of 91.53 mg/100 g for all the samples and treatments studied. The MAP non perforated sample stored at T2 recorded maximum Hunter 'L' and '-a' colour values than all other samples. A significant decrease in AA content was observed in all the samples with maximum loss (53.77 %) in unsealed sample stored at T2, whereas MAP (3 perforations) sample stored at T1 retained maximum AA (90.50 %). Sensory quality analysis revealed that MAP (3 perforations) sample stored at T1 was in acceptable quality, with good appearance and overall acceptance. The study shows that shelled green peas can be stored in MAP with 3 perforations (0.4 mm dia) in the temperature range of 4 to 10 °C and 90–94 % RH to extend shelf life with marketable quality for 24 days.

Keywords Green pea · Modified atmosphere packaging · Total phenol content · Ascorbic acid · Colour · Sensory quality

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Introduction

Green or garden pea (*Pisum sativum* var. *sativum* L) is one of the three types of edible peas (green pea, sugar or snow pea and snap or sugar snap pea). To retain post harvest quality, peas are harvested before physiological maturity is reached. Green pea has a tough pod which is separated from peas and discarded, prior to eating. Shortly after harvest, loss of sweetness and crispness, as well as degreening and the development of mealiness, may degrade the quality of snow pea pods (Pariasca et al. 2001). Pea is a non-climacteric, highly respiring (>60 mL CO_2/kg/h at 5 °C) and perishable commodity that can be stored at temperatures near 0 °C, to extend its shelf life for maximum 2 weeks (Scetar et al. 2010; Kader 1992; Suslow and Cantwell 1998). Most often green peas are frozen or processed in developed countries like U.S. (Basterrechea and Hicks 1991) whereas; peas are harvested just before physiological maturity is attained and used mainly for culinary purpose, due to inadequate freezing and processing facilities in developing countries. Freezing converts liquid water into ice, which greatly reduces microbial and enzymatic activities, however oxidation and respiration are weakened effectively by low temperature (Haiying et al. 2007). Freshly harvested vegetables continue their respiration and metabolic processes which are associated with deterioration of products during storage (Sharma and Gupta 2006). The rate of respiration primarily decides the storage quality and shelf life under different storage environment.

Good quality peas should be uniformly bright green, fully turgid and free from decay and damage caused by black calyxes, freezing, insects, mechanical, mildew or other diseases for better market price. Freezing is an energy intensive preservation method below 0 °C and requires costly infrastructure with uninterrupted power supply. The main disadvantage of freezing is that it requires uninterrupted power supply; to maintain the frozen condition without temperature fluctuation for maintaining better quality during storage. Peas are graded primarily based on appearance and freezing temperature abuse adversely affects the appearance of peas, when peas are transferred from frozen condition to atmospheric condition due to thawing and wilting. Freezing itself will decrease food quality (Haiying et al. 2007). Quick freezing is thought to better keep the shape, nutrition and taste of food (Lester 1995). Even quick freezing of pre treated mushroom, green cauliflower, navy bean and pea pod would produce smaller ice crystals, which cause some irreversible damage to microstructures. The impacts of freezing on food quality are directly related with the growth of ice crystals, which can break cellular walls (Anzaldua-morales et al. 1999). Modified atmosphere packaging (MAP) is of the new applied food packaging techniques offering a prolonged shelf life of respiring products (Day 1996). The MAP of vegetable combined with cold storage is considered as the best way to prolong the shelf life period (Sandhya 2010), maintain sensory and microbiological quality of fresh-cut produce (Philips 1996). MAP is relatively low cost and easy to use (Sharma and Gupta 2006) as it reduces respiration, moisture loss and decay and/or extends the shelf life of the products (Scetar et al. 2010; Day 1996). This is a simple postharvest handling practice that should be promoted for vegetables at the production level for local markets (Kinyuru et al. 2011) due to lack of freezing and processing facilities.

Despite many advantages of MAP, a very little information is available on the MAP of shelled green pea. The shelf life of shelled peas packed in 25 μm thickness low and high density polyethylene (LDPE and HDPE) was 45, 17, 7 and 4 days when stored at the temperatures of −11, 5, 15 °C and room temperature, respectively (Sandhya and Singh 2004). Pariasca et al. (2001) studied the effects of pre-cooling, MAP and CA storage on the storability of snow pea pods (*Pisum sativum* L. var. *saccharatum*) at 5 °C. Increased CO_2 concentration to 2.6 or 4.7 kPa, combined with 21 or 2.4 kPa O_2, at 1 °C maintained the appearance, as well as chlorophyll, soluble sugar and protein contents of stored snow peas (Ontai et al. 1992). For highly respiring produce such as mushrooms, peas and broccoli, traditional films like LDPE, polyvinyl chloride (PVC), ethylene vinyl acetate (EVAC), oriented polypropylene (OPP) and cellulose acetate are not sufficiently permeable. The use of perforated films was recommended by Emond et al. (1991); Fishman et al. (1996). The highly permeable micro-perforated ones are most suitable for packaging highly respiring produce (Scetar et al. 2010). However, the micro-perforated films are special films which are expensive and not available everywhere (Rai et al. 2009). A combination of low temperature storage and closed polythene packaging has a very good preservation effect on the quality of vegetable like snap beans. Non-perforated polymeric films yield low O_2 and low CO_2 concentrations because the CO_2 permeability of these materials is generally 3 to 6 times that of O_2 permeability. These materials are suitable for less CO_2 tolerant commodities such as mango, banana, grapes and apples (Mahajan et al. 2006).

The practice of using MAP of green peas in recent years by retail stores, local markets and local vendors for packaging, storage and marketing of shelled peas has been increased by many folds. In local markets and mandis, unshelled green peas marketed by covering wet gunny bags and/or spraying water frequently with an intention to maintain freshness. However, this practice deteriorates the unshelled green peas quality if the peas remain unsold within couple of days. Further, the use of polymeric film bags (with or without punched holes) without any proper scientific background for packaging, storage and marketing of shelled green peas by retail stores, local vegetable markets and local vendors has been increased in recent days. In pack CO_2 concentration in non perforated film bags would accumulate beyond critical limit due to increase in respiration rate depending up on the temperature. On the other hand, there would be a more loss of moisture due to desiccation of fresh shelled peas, when stored in film bags having punched holes with more perforated area. Therefore, because of the very little work available on the MAP of shelled peas, the objective of the present study was to investigate the qualitative changes of shelled green peas under modified atmosphere packaging (perforated and non-perforated) at different storage conditions and period.

Materials and methods

Raw material

Fresh, bright green, fairly well filled and fully turgid green pea pods free from decay and damage were harvested from farmer's field early in the morning and transported to the Food Packaging and Transportation Laboratory. Immediately on procurement, green pea pods were thoroughly mixed and divided equally in to two lots, prior to pre-cooling. One lot was pre-cooled at 10 ± 1 °C; and another lot was pre-cooled at 4 ± 1 °C for 2 h in walk in cold room (Sheel Biotech Ltd., India). Pre-cooled pea pods of both the lots were shelled manually, and sorted to remove misshapen, damaged, under and over sized peas from bright green, uniform size and fully turgid green peas of both the lots separately at their respective storage temperatures. The sorted shelled peas were treated in 0.5 % sodium hypochlorite for 1 min; then drained off surface moisture using blot paper prior to packaging. Both the lots of pretreated peas were pre-cooled further for 4 h at their respective storage temperatures.

Modified atmosphere packaging and storage

Modified atmosphere (MA) was created using low density polyethylene (LDPE) film packages having 107 μm thickness and size of 0.022 m^2. The pre-cooled shelled green peas (200 ± 2 g) were packaged in perforated (3 and 6 perforations having 0.4 mm dia each) as well as in non perforated LDPE film packages and stored at two different temperatures. Two temperatures of T1 (4 ± 1 °C) and T2 (10 ± 1 °C) were selected as storage temperature to evaluate the suitability of modified atmosphere in extending the shelf life. First lot of packaged green peas was stored at T1 (4 ± 1 °C and 94 ± 2 % RH). For this lot, the sample were designated as i) Unsealed (US + T1); ii) 0 perforation (0P + T1); iii) 3 perforations (3P + T1); iv) 6 perforations (6P + T1). The second lot was stored at T2 (10 ± 1 °C at 90 ± 2 % RH). For this second lot, the samples were designated as I) Unsealed (US + T2); II) 0 perforation (0P + T2); III) 3 perforations (3P + T2); IV) 6 perforations (6P + T2). Three package samples from each lot stored at two different temperatures were removed at each period of storage (8, 16 and 24 days) for analysis of quality and sensory characteristics.

Headspace gas concentration analysis

In pack headspace gas concentration was measured in sample packages by using a portable gas analyzer (Model 902D Dualtrak, Quantek, USA). The instrument evaluated the headspace by means of an electrochemical and an infrared sensor (sensitivity: 0.1 % O_2; 0.1 % CO_2, accuracy: 0.1 % O_2; 0.2 % CO_2) for O_2 and CO_2 concentrations, respectively. The instrument was calibrated with the standard O_2 and CO_2 gases. The drawn samples were fed simultaneously to the O_2 and CO_2 sensors and concentrations of O_2 and CO_2 were directly read on the digital display panel of the instrument.

Weight loss

During storage period, the weight loss (WL, %) of the sample was calculated as per cent change in weight based on the initial and final weight using a laboratory level weighing scale having 0.01 g accuracy (Scaltec Instruments, Germany).

Total phenol content

Total phenol content (TPC) was determined as per McDonald et al. (2001) using Folin Ciocalteu reagent. One g of peas was extracted with 10 ml of methanol: water (50:50, *v*/*v*) and 0.5 ml of the diluted (1:10) extract or the standard phenol compound (gallic acid) was mixed with 5 ml of Folin Ciocalteu reagent (1:10 diluted with distilled water) and 4 ml of aqueous Na_2CO_3 (1 M). The mixture was allowed to stand for 15 min and optical density of the mixture was determined against the blank at 765 nm with the help of UV-Vis spectrophotometer (1800-Shimadzu). TPC values were expressed in terms of the standard reference compound as gallic acid equivalent (mg/100 g fresh weight of peas).

Colour evaluation

The colour of peas was measured with the help Hunter Lab Miniscan XE Plus colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA) (Hunter 1975). The colour values of peas were expressed as Hunter color 'L' value ('100 L' and '0 L' indicate white and black), 'a' value ('−a' and '+a' values indicate greenness and redness) and 'b' value ('−b' and '+b' values indicate blue and yellow). The colorimeter was calibrated using standard white and black colour plates prior to measurement of peas colour. For colour determination of peas sample, thick layer of peas were formed by filling peas in petri plates then reflectance spectra was measured at 3 different points on the sample surface and then the mean value was obtained.

Ascorbic acid

Ascorbic acid was determined quantitatively as per the modified 2, 6-dichlorophenolindophenol (DIP) method (Klein and Perry 1982). For extraction, 1 g of sample was homogenized using a tissue homogenizer (Labco, New Delhi, India) for 1 min with 10 ml of 1 % meta-phosphoric acid (*v*/*v*) over ice. The extract was centrifuged at 3000 g in a cold centrifuge (MP 400-R, Eltek Limited, India) at 3 °C for 15 min. One ml of the supernatant was mixed with 9 ml of 0.05 mM of DIP using a vortex shaker (Labco, New Delhi, India) for 15 s and absorbance of solution was measured against the blank at 515 nm with the help of UV-Vis spectrophotometer (1800-Shimadzu).

Sensory quality evaluation

Sensory quality evaluation was done for off-flavor and palatability (Miyazaki 1985) and appearance of peas (Sakata and Arisumi 1983). At each sampling time, some peas were boiled for 2 min and evaluated for off-flavour and palatability by a panel of five semi-trained persons, based on the following grades modified from (Miyazaki 1985). Off-flavor: 1 = none (no off-flavor can be detected); 2 = slight; 3 = strong; 4 = severe (extremely strong off-flavor can be detected). Palatability: 1 = good (liked or preferred taste); 2 = fair; 3 = poor; 4 = inedible (severely disliked taste). Appearance, a subjective index, was modified from (Sakata and Arisumi 1983): 1 = bright green, firm, fully turgid and free from defects; 2 = minor defects appearing and slightly wilted peas; 3 = obvious minor defects and wilted peas; 4 = brown and discolored peas, obvious defects on peas and completely wilted peas.

Statistical analysis

The statistical analysis of data obtained was carried out to analyze the differences among the treatments during storage period. All the experiments were performed in triplicate. Two-way analysis of variance (ANOVA) and the significant difference of the data at $p < 0.01$ was carried out using a statistical package (Agristat, IASRI, New Delhi) and the means were plotted to draw out inferences.

Results and discussion

Headspace gas concentration

Shelled green peas stored under MAP (perforated and non perforated) at two different temperature and at different storage periods, were evaluated for headspace gas composition of O_2 and CO_2 (Fig. 1). It is clear from the Fig. 1 that the steep decrease in O_2 and corresponding increase in CO_2 till 5th day which could be ascribed to an initial adjustment and respiratory behavior of shelled peas in the transient state of stabilization and equilibration which resulted in-pack accumulation of CO_2. The lowest (4.0–6.4 %) and highest %O_2 (8.9–12.6) was observed in the samples stored in MAP without perforations and with perforations, respectively, with an average 5.2 and 10.32 % O_2. It was moderate and slow decrease in O_2 and increase in CO_2 was observed from 5th to 10th day and from 10th to 15th day of storage, respectively in all the packaged samples. The slow decrease in O_2 and increase in CO_2 was observed till 20 days in all the samples barring in the MAP samples having 6 perforations at both the temperatures. In the case of MAP samples having 3 perforations stored at both the temperatures, the in-pack gas concentration was well adjusted as compared to the MAP samples with an overall average 7.17 and 14.07 % of O_2 and CO_2, respectively during storage period.

Weight loss

Weight loss (WL, %) of shelled green peas under MAP (perforated and non perforated) and unsealed packages stored at two different temperatures is shown in Fig. 2. Among all the

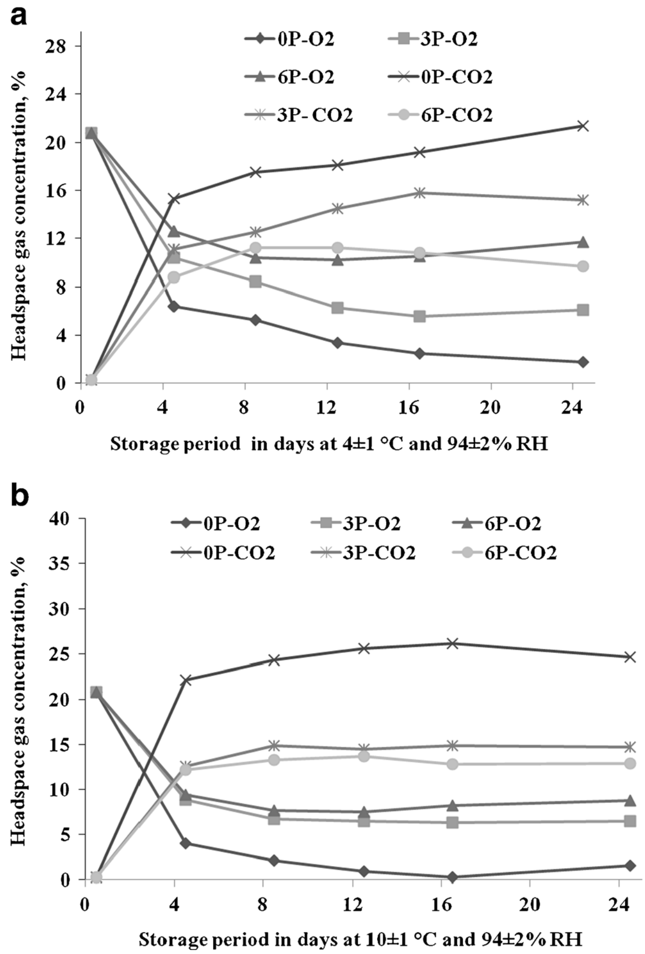

Fig. 1 **a** Changes in O_2 and CO_2 concentration inside the modified atmosphere packaging containing shelled green peas stored at T1 (4 ± 1 °C and 94 ± 2 % RH) and **b** at T2 (10 ± 1 °C at 90 ± 2 % RH) (n = 3); 0P, 3P and 6P are zero, 3 and 6 perforations

packaging treatments, storage period and interaction of treatments and storage period, the decrease in weight was statistically significant at 99 % confidence level with p-value < 0.01 which indicated a major change in WL during storage (Table 1). The increase in WL was observed in all the samples with varying magnitude. However, the influence of temperature and RH on weight loss during storage period, registered the highest weight loss in unsealed sample stored at T2 (Fig. 2). The lowest WL was observed in MAP samples having zero perforation followed by 3 perforated sample stored at T1 due to the effect of low temperature, high RH, low in-pack O_2 and high CO_2 concentrations which is in conformation with the earlier reported results of Sharma and Gupta (2006); Sandhya and Singh (2004). Unpackaged tomatoes lost 3.4 % of their initial weight, while under optimal MA; the weight loss was considerably less after 35 days. (Tano et al. 2007).

The WL was in the range of 0.18 to 3.54 %, 0.21 to 6.48 and 0.31 to 9.64 % after 8, 16 and 24 days of storage, respectively. On 24th day of storage, an average WL observed to be 0.31,

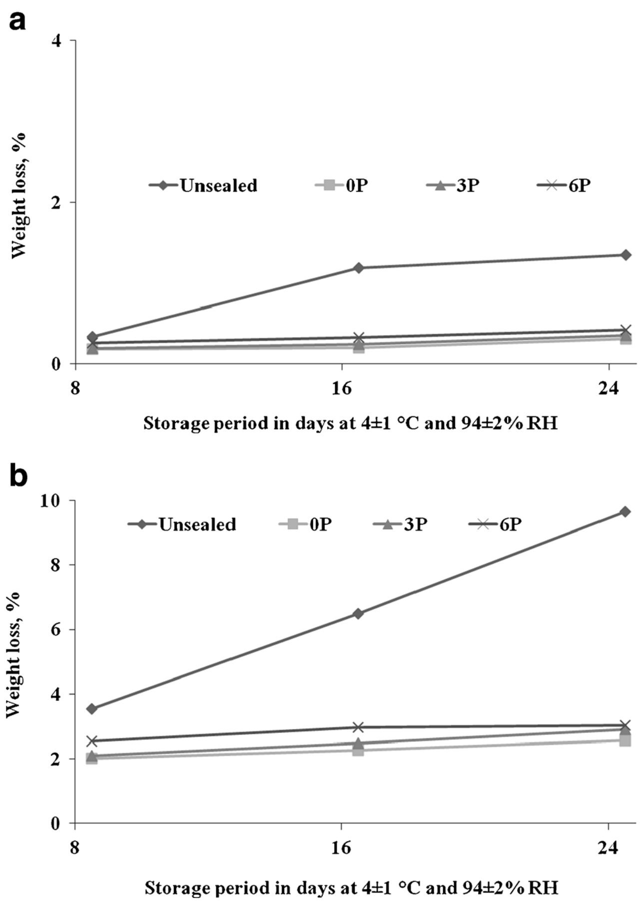

Fig. 2 **a** Weight loss (%) of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and **b** at T2 (10 ± 1 °C at 90 ± 2 % RH) (n = 3) 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

0.39, 1.35, 2.57, 2.97 and 9.64 % in zero perforated MAP sample (0P + T1), perforated (3P + T1 and 6P + T1) MAP samples, unsealed sample (US + T1), zero perforated MAP sample (0P + T2) and perforated (3P + T2 and 6P + T2) MAP samples and unsealed sample (US + T2), respectively (Fig. 2).

Total phenolic content

Phenolic compounds are chemicals in plants largely responsible for colour, metabolism and defensive mechanisms. Induction of phenolic compounds is a physiological response to infections or injuries (Amanatidous et al. 2000). Any changes in storage environment surrounding the product stimulate the cells to induce more phenolics in an attempt to initiate the response as defensive mechanism. The total phenolic content (TPC) of freshly shelled green peas was 91.53 mg/100 g fresh weight of peas. The increase in TPC was highest in non-perforated samples stored at both the temperatures which could be attributed to more stressful condition created by high levels of in-pack CO_2 concentrations. Whereas unsealed samples was observed to be least increase in TPC. The TPC was in the range of 93.17 to 131.87, 95.43 to 143.33 and 102.47 to 161.54 mg/100 g after 8, 16 and 24 days of storage, respectively (Fig. 3). Figure 3a, b shows the phenolic content of peas during storage was increased in all the treatments which may be due to an increase in the activity of the phenylpropanoid pathway under stressful conditions (change in temperature and in-pack gas) and as evident from synthesis and accumulation of phenolics compounds (Kang and Saltveit 2002). Among all the packaging treatments, the increase of total phenolic content (TPC) was statistically significant at 99 % confidence level with p-value < 0.01 which indicated a major change in TPC during storage (Table 1).

Colour

Colour is one of the most important quality parameters of consumer acceptance. Good quality peas should be uniformly bright green and fully turgid for better market price. Degreening takes place shortly after harvest which may degrade the quality of snow pea pods (Pariasca et al. 2001). Low temperature, less light, reduced moisture loss and respiration rate

Table 1 ANOVA indicating the qualitative changes of shelled green peas under modified atmosphere packaging and storage conditions (n = 3)

Parameter	Treatment (a)				Storage (b)				a × b (Interaction)			
	DF	MS	S/NS	CD	DF	MS	S/NS	CD	DF	MS	S/NS	CD
WL	7	45	S	0.02	2	31.8	S	0.01	14	5.9	S	0.03
TPC	7	2121	S	0.9	3	5442	S	0.62	21	358	S	1.74
L	7	4.9	S	0.3	3	27.9	S	0.20	21	0.10	S	0.57
'-a'	7	3.3	S	0.4	3	8.3	S	0.30	21	0.93	S	0.86
AA	7	117	S	1.3	3	485	S	0.93	21	29	S	2.62
OFL	7	5.6	S	0.4	2	5.6	S	0.24	14	0.55	S	0.69
PLT	7	8.3	S	0.5	2	6.6	S	0.28	14	0.54	S	0.80
APP	7	6.7	S	0.5	2	5.7	S	0.33	14	0.05	NS	0.93

DF: degree of freedom; *MS*: mean sums of squares; *S*: significance; *NS*: non-significance; *CD*: critical difference ($p \leq 0.01$); *WL*: Weight loss; *TPC*: Total phenol content; '*L*' = L value; *a*: '-a' value; *AA*: Ascorbic acid; *OFL*: Off-flavour; *PLT*: Palatability; *APP*: Appearance

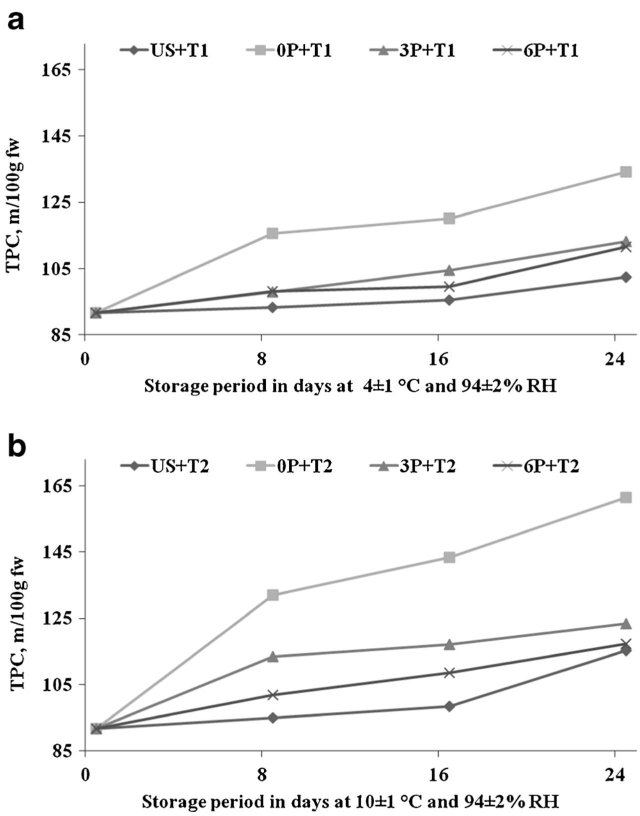

Fig. 3 **a** Total phenolic content (mg/100 g fw) of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and **b** at T2 (10 ± 1 C at 90 ± 2 % RH) (n = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

help to maintain green colour or to reduce green colour loss. The MAP technique slows down respiration, reduce moisture loss and decay and/or extend the shelf life of the products (Scetar et al. 2010; Day 1996). The Hunter colour 'L' and '-a' values of shelled peas were measured before (on zero day) and during storage to investigate the effect of MAP and temperature on extent of colour change and the colour values plotted in Fig. 4a, b. Among all the packaging treatments, storage period and interaction of treatments and storage period, the change in 'L' and '-a' values was statistically significant at 99 % confidence level with p-value <0.01 (Table 1). The unsealed samples at both the temperatures recorded maximum 'L' values as compared the all perforated treatments stored in corresponding temperatures (Fig. 4a). In all the treatments, the 'L' values (whiteness) increased with storage period. At the end of storage, the maximum 'L' value (49.0) was observed in US + T2 whereas the samples 3P + T1 and 0P + T1 recorded minimum 'L' values (about 46.0), which could be due to the better in-pack modified atmosphere and low temperature together for 3P + T1 and only low temperature effect for 0P + T1 as compared to its counterpart treatment i.e. 0P + T2. This latter treatment recorded maximum 'L' value than other treatment at T2 temperature (Fig. 4a).

The '-a' values ('-a' indicates greenness) shifted towards positive sign indicating decrease in green colour during storage period in all the treatments with maximum decrease in green colour (from −9.3 to −5.48) in the sample 0P + T2(Fig. 4b). During storage, treatment US + T1 followed by perforated MAP samples stored at T1 temperatures showed minimum change in '-a' values during storage as compared to their counterpart samples stored at T2 temperatures which could be attributed to the effect of low temperature which resulted in minimum loss of green colour. The '-a' values were in the range of −8.60 to −7.66, −8.36to −5.28 and −8.22 to −3.35 after 8, 16 and 24 days of storage, respectively (Fig. 4b).

Ascorbic acid

Ascorbic acid (AA) is considered to be highly sensitive to processing and storage conditions and it is often used as a marker for product quality deterioration (Davey et al. 2000). The decrease in AA content was observed in all the samples with maximum loss in unsealed package sample stored at T2 (Fig. 5). Among all the treatments, storage period and interaction of treatments and storage period, the decrease in weight was statistically significant at 99 % confidence level with p-value < 0.01 which showed a major change in AA during storage (Table 1). Initial content of AA was 38.7 mg/100 g and it reduced to 17.89 mg/100 g (53.77 % loss) in the treatment US + T2 at the end of storage whereas the treatment 3P + T1 retained maximum AA (35.02 mg/100 g) with minimum loss of 9.5 % at end of the storage which could be attributed to the combined effect of better in-pack gas adjustment in MAP having 3 perforations and temperature 4 ± 1 °C and 94 ± 2 % RH. The content of AA was in the range of 32.99 to 38.13, 26.40 to 36.32 and 17.89 to 35.02 mg/100 g after 8, 16 and 24 days of storage, respectively (Fig. 5). Similar findings were reported in a study on modified atmosphere packaging storage of green bell peppers showed that samples packaged with the PE films did not exhibit significant changes in ascorbic acid content during shelf life studies and at the end of the cold storage (14th day) at 5 C the PE packaged peppers retained the93.0 % of the initial ascorbic acid present in bell peppers (Manolopoulou et al. 2010).

Sensory quality

Changes in off-flavour, palatability and appearance during storage as sensory quality attributes were evaluated as per the methods described by Miyazaki (1985); Sakata and Arisumi, (1983). Peas are graded primarily based on external appearance. Good quality peas should be uniformly bright green, fully turgid and free from decay and damage caused by pre and post harvest factors for better market price. Till 16th day of storage, there was no off-flavour development (score was <1.0) in an all the samples, except the sample

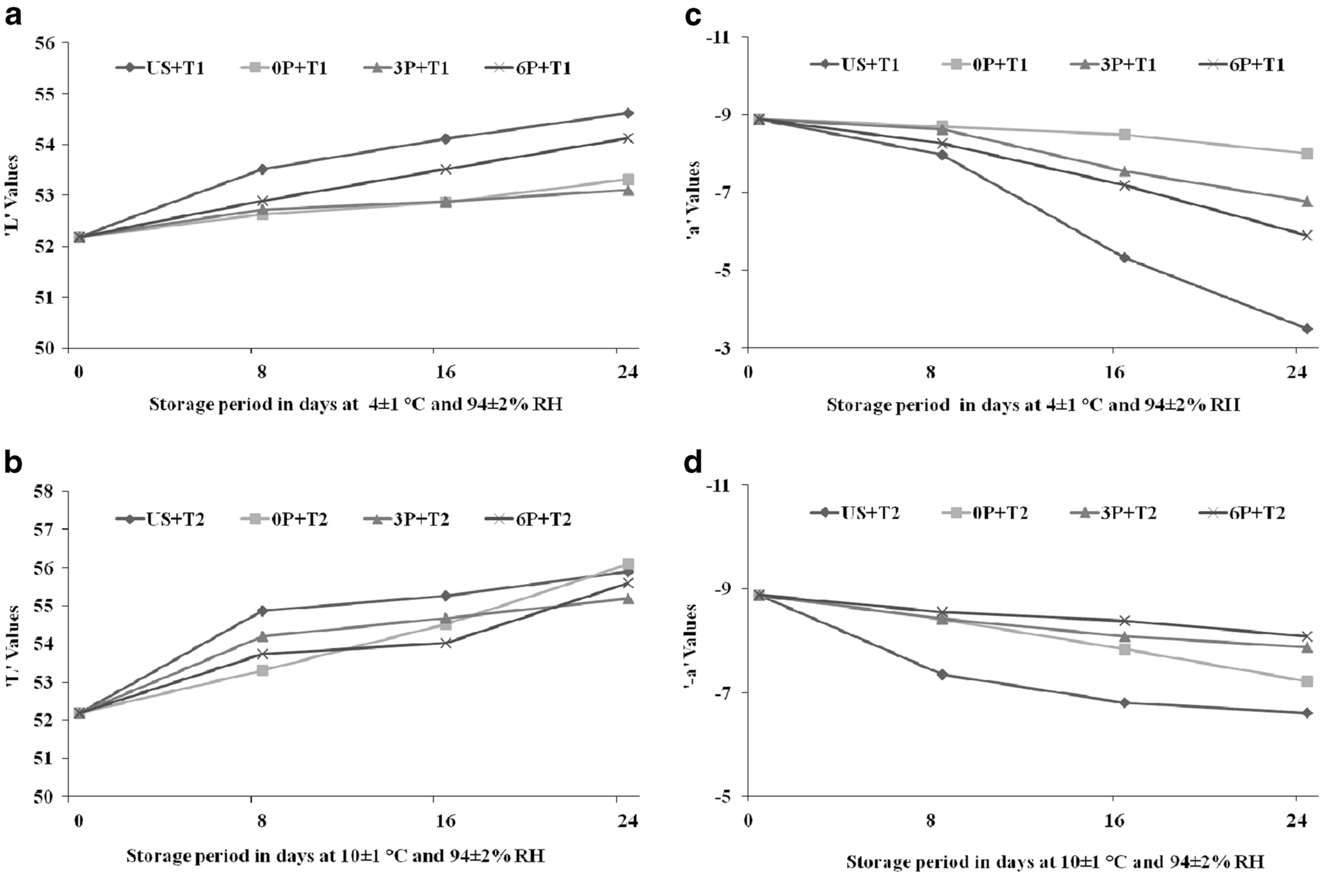

Fig. 4 **a** CIE L* values of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and **b** CIE L* values of shelled green peas stored under MAP at T2 (10 ± 1 °C at 90 ± 2 % RH) **(c).** CIE a * values of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) **(d)** CIE a* values of shelled green peas stored under MAP at T2 (10 ± 1 °C at 90 ± 2 % RH) (*n* = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

0P + T2 which had experienced with slight off-flavour development. At the end of storage, all the samples except the samples 0P + T2 and 0P + T2; scored less than 2.0 with an average score of 1.4 as off-flavour score. The samples 0P + T2 and 0P + T2 were observed with strong and severe off-flavour development at the end of storage, which could be attributed to a very low level O_2 causing anaerobic conditions (25) whereas, the samples 3P + T1, US + T1, 6P + T1, US + T2, 6P + T2 and 3P + T2 scored 1.3, 1.3, 1.3, 1.5, 1.5 and 1.8, respectively, with an average score of 1.4 (Fig. 6). At the end

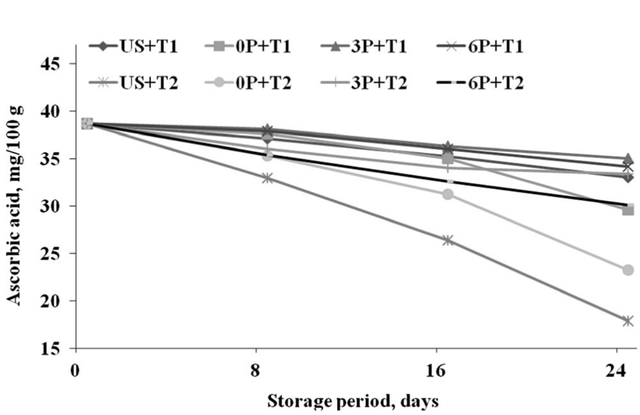

Fig. 5 Ascorbic acid (mg/100 g) of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and T2 (10 ± 1 °C at 90 ± 2 % RH) (*n* = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

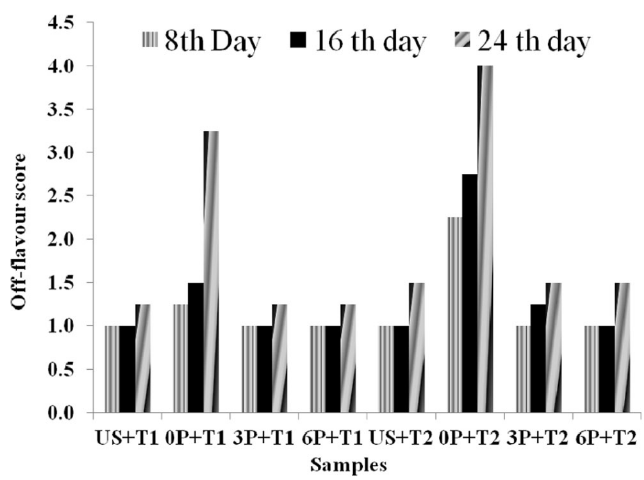

Fig. 6 Off-flavour of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and T2 (10 ± 1 °C at 90 ± 2 % RH) (*n* = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

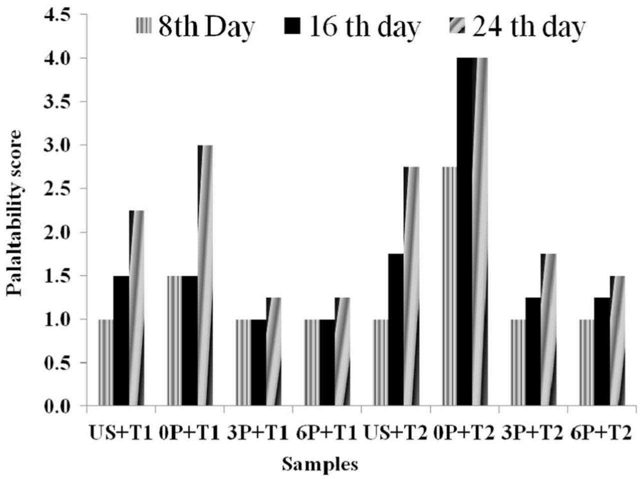

Fig. 7 Palatability of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and T2 (10 ± 1 °C at 90 ± 2 % RH) (n = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

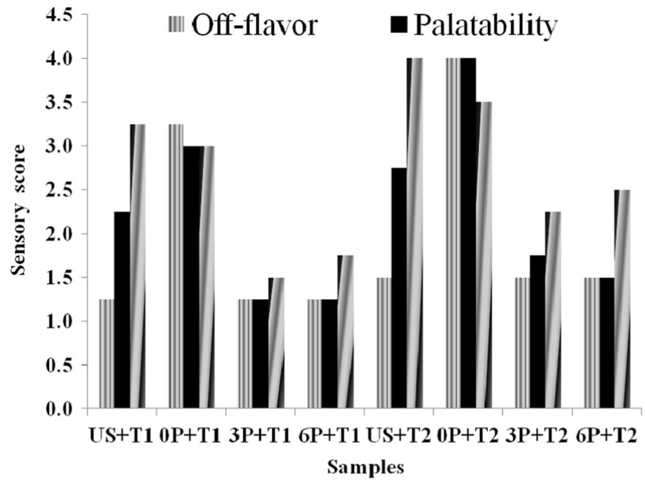

Fig. 9 Overall sensory quality of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and T2 (10 ± 1 °C at 90 ± 2 % RH) (n = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

of 8th day, all the samples (except 0P + T1 and 0P + T2) scored minimum score (1.0 = good: liked or preferred taste) for palatability, whereas the samples 0P + T1 and 0P + T2 had scored 1.5 and 2.8, respectively. At the end of storage, the perforated samples stored at T1 temperature scored an average score of 1.3 and their counterpart samples stored at T2 temperature scored an average score of 1.5 whereas, non perforated samples stored at both the temperatures adjudged as poor and ineligible (Fig. 7).

Since appearance is a subjective index (Sakata and Arisumi 1983), colour (bright green to brown colour and discolouration), turgid, extent of defects, wilting were considered while evaluation of peas for appearance. The three samples 3P + T1, 6P + T1 and 3P + T2 had the minimum values of appearance score at the end of 8th day and 16th day (1.0 and 1.3, respectively) (Fig. 8). At these two storage period, the non-perforated samples had an average score of about 1.6

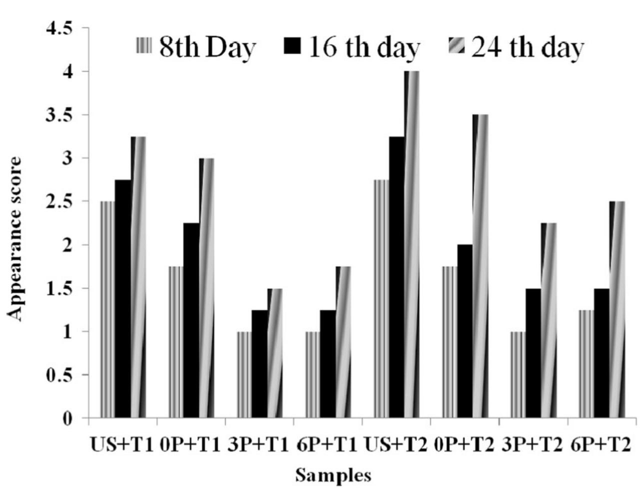

Fig. 8 Appearance of shelled green peas stored under MAP at T1 (4 ± 1 °C and 94 ± 2 % RH) and T2 (10 ± 1 °C at 90 ± 2 % RH) (n = 3); 0P, 3P and 6P are zero, 3 and 6 perforations; US: unsealed

and 1.75, respectively. Whereas, the unsealed samples had about 2.6 and 3.0 an average score, respectively (Fig. 8). At the end of storage (24th day), the samples 3P + T1 continued to be secure good score (minimum value) for appearance as it scored 1.5 followed by 6P + T1 with score of 1.75 due to low temperature and better in-pack adjustment whereas rest of the treatments scored more than 3.0 barring the treatments 3P + T2 and 6P + T2 with an average score of 2.1. Unsealed samples were not in acceptable condition due to poor appearance (Fig. 8). Figure 9 shows the changes in sensory quality attributes (off-flavour, palatability and appearance) at the end of storage. It is more clear from the Fig. 9 that non-perforated MAP samples scored maximum sensory score (poor acceptance by the sensory evaluation panel) which could be attributed to the very rapid depletion of in-pack O_2 concentration than healthy adjustment of in-pack O_2 resulted in off-flavour development, discoloration (green to brown) and poor appearance. Control samples (unsealed) were scored minimum sensory score (better acceptance by the sensory evaluation panel) on 8th day and then trend was reversed which could be attributed loss of moisture and more respiration rate. The sample 3P + T1 was secured minimum sensory score (better acceptance) and this was followed by 6P + T1, 3P + T2 and 6P + T2 (Fig. 9).

Conclusion

Modified atmosphere packaging (MAP) having 3–6 perforations (0.4 mm dia each) combined with cold room condition (4 to 10 °C and 90–94 % RH) was found to be beneficial for creating good in-pack modified atmosphere, reducing weight loss, least colour change, maximum retention of ascorbic acid and sensory scores (1.0 to 1.75) for perforated samples at both the temperatures) of shelled green peas, as compared to all other non-perforated unsealed packaging treatments. The study reveals that shelled green peas can be stored under MAP with 3–6 perforations per bag area of $0.022 m^2$ at the temperature range of 4 to 10 °C and 90–94 RH to extend the shelf life with marketable quality for 24 days. The study would be useful to retail stores, local markets and local vendors for packaging, storage and marketing of shelled peas where frozen conditions add to the overall cost of the shelled peas.

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References

Amanatidous A, Slump RA, Gorris LGM, Smid EJ (2000) High oxygen and high carbon dioxide modified atmospheres for shelf life extension of minimally processed carrots. J Food Sci 65(1):61–66

Anzaldua-morales A, Brusewitz GH, Anderson JA (1999) Pecan texture as affected by freezing rates, storage temperature and thawing rates. J Food Sci 64(2):332–335

Basterrechea M, Hicks JR (1991) Effect of maturity on carbohydrate changes in snap pea pods during storage. Sci Hort 48(1–2):1–8

Davey MW, Montagu VM, Inze D, Sanmartin M, Kanellis A, Smirnoff N, Benzie IJJ, Strain JJ, Favell D, Fletcher J (2000) Plant L-ascorbic acid: chemistry, function, metabolism, bioavailability and effects of processing. J Sci Food Agric 80(7):825–860

Day A (1996) High oxygen modified atmosphere packaging for fresh prepared produce. Postharvest News Inf 7(3):31–34

Emond JP, Castaigne F, Toupin CJ, Desilets D (1991) Mathematical modeling of gas exchange in modified atmosphere packaging. Trans ASAE 34(1):239–245

Fishman S, Rodov V, Ben-Yahoshua S (1996) Mathematical model for perforation effect on oxygen and water vapour dynamics in modified atmosphere packages. J Food Sci 61(5):956–961

Haiying WZ, Shaozhi Z, Guangming C (2007) Experimental study on the freezing characteristics of four kinds of vegetables. LWT Food Sci Technol 40(6):1112–1116

Hunter S (1975) The measurement of appearance. Wiley, New York, pp. 304–305

Kader AA (1992) Postharvest Biology and Technology: An overview and modified atmosphere during transport and storage. In: Kader, A. A. (ed.). 1992. Postharvest Technology of Horticultural Crops. Univ California Pub. 3311, USA, 15–17 and 85–92

Kang H, Saltveit ME (2002) Antioxidant capacity of lettuce leaf tissue increases after wounding. J Agric Food Chem 50(26):7536–7541

Kinyuru JN, Kahenya K, Muchui PM, Mungai H (2011) Influence of post-harvest handling on the quality of snap bean (*Phaseolus vulgaris* L.). J Agri Food Technol 1(5):43–46

Klein BP, Perry AK (1982) Ascorbic-acid and vitamin-a activity in selected vegetables from different geographical areas of the United States. J Food Sci 47(3):941–945

Lester EJ (1995) Freezing effects on food quality. Marcel Dekker Inc, New York

Mahajan PV, Oliveira FAR, Sousa MJ, Fonseca SC, Cunha LM.(2006) An Interactive Design of MA-Packaging for Fresh Produce. Book Chapter. In: Hui, Y.H. Handbook of Food Science, Technology and Engineering. Volume 3. CRC Press, USA.

Manolopoulou H, Xanthopoulos G, Douros N, Lambrinos GR (2010) Modified atmosphere packaging storage of green bell peppers: quality criteria. Biosyst Eng 106(4):535–543

McDonald S, Prenzler PD, Antolovich M, Robards K (2001) Phenolic content and antioxidant activity of olive extracts. Food Chem 73(1): 73–84

Miyazaki T (1985) Keeping qualities of broccoli by seal-packaging with plastic bags and ethylene removing agent. Japan Pack Res (in Japanese with English Abstract) 6:1–6

Ontai SL, Paull RE, Saltveit MEJ (1992) Controlled atmosphere storage of sugar peas. Hort Sci 27(1):39–41

Pariasca JAT, Miyazaki T, Hisaka H, Nakagawa H, Sato T (2001) Effect of modified atmosphere packaging (MAP) and controlled atmosphere (CA) storage on the quality of snow pea pods (*pisum sativum L. var. saccharatum*). Postharvest Biol Technol 21(2):213–223

Philips C (1996) Review: modified atmosphere packaging and its effects on the microbiological quality and safety of produce. Int J Food Sci Technol 31(6):463–479

Rai DR, Jha SN, Wanjari OD, Patil RT (2009) Chromatic changes in broccoli (Brassica oleracea italic) under modified atmospheres in perforated film packages. Food Sci Technol Int 15(4):387–395

Sakata Y, Arisumi K (1983) Studies on the flower colours of sweet pea. II. Constitution of the anthocyanin and flavonol pigments in various strains of garden sweet pea. Bulletin, faculty of agriculture. Kagoshima University 33:13–19

Sandhya (2010) Review: modified atmosphere packaging of fresh produce-current status and future needs. LWT-Food Sci Technol 43(3):381–392

Sandhya, Singh AK (2004) Packaging of shelled peas in high-density polyethylene. J Res Punjab Agri Uni 41(1):110–118

Scetar M, Kurek M, Galic K (2010) Trends in fruit and vegetable packaging–a review. Croatian J Food Technol Biotechnol Nutri 5(3–4): 69–86

Sharma SR, Gupta AK (2006) Packaging of shelled peas in high density polyethylene. J Res Punjab Agri Uni. 43(3):208–213

Suslow TV, Cantwell M (1998) Peas: snow and snap pod peas. Perishables handling quarterly. Univ of calif. Davis CA 93:15–16

Tano K, Oule MK, Doyon G, Lencki RW, Arul J (2007) Comparative evaluation of the effect of storage temperature fluctuation on modified atmosphere packages of selected fruits and vegetables. Postharvest Biol and Technol 46(3):212–221