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# MODIFIED ATMOSPHERE POLYETHYLENE PACKAGES MAINTAIN THE QUALITY OF SNAP BEAN PODS DURING STORAGE

**El-Bassiouny, Rawia E.I.**
**Vegetable Handling Department, Horticulture Research Institute, Agriculture Research Center, Giza.**

## ABSTRACT

The effects of different packages and modified atmosphere packaging, MAP, on the keeping quality of green bean pods stored at 7°C were determined. A new polyethylene sealed package, which is made in Egypt, retained the best quality among the various imported packages that were included in the experiment. The only disadvantage of the new package was the unacceptable odor as storage exceeded 10 days. The stretch film and polyethylene lining were second and third best. Further, while the perforated poly propylene packages were inferior to the above mentioned packages, they were superior to the bulk loose package, which was the worst, by far. On the other hand, to avoid the unacceptable odor associated with prolonged storage, macro perforated polyethylene films of numerous pin holes were used in a subsequent experiment and were successful in maintaining green beans quality due to atmosphere modification (passive), besides having the added advantage of maintaining the high relative humidity necessary to avoid wilting during postharvest handling.

**Keywords:** *Phaseolus vulgaris,* firmness, turgidity, off-odor, color, visual quality, $CO_2$, $O_2$, correlation, PVC, pin holes.

## INTRODUCTION

Green beans, known also as snap beans ( *Phaseolus vulgaris* L.), are the second largest Egyptian vegetable crop grown for local consumption and export (Ministry of Agriculture and land reclamation data). There is a year-round foreign trade in Egyptian fresh beans, which are highly prized in Europe. The foreign demand for snap beans has increased the importance of postharvest handling and quality maintenance. Green beans are harvested at an immature developmental stage, have a high respiration rate and a short storage life, only 7-10 days at 5 - 8°C (Watada and Morries, 1966; Ryall and Lipton, 1979; Hardenburg *et al.*, 1986; Snowdon, 1992; Cantwell and Kasmire, 2002).

Deterioration of quality attributes commonly occurs during postharvest handling of the fresh product. Weight loss is cumulative and generally linear with time in storage, the increase in limpness and shrivelling and subsequently the loss of crispness follow weight loss of green beans (Sistrunk *et al.*, 1989; Trail *et al.*, 1992; Jimeneze *et al.*, 1998). The most obvious indicator of beans quality is color, which changes from a desirable bright green to an objectionable yellowish color (Trail *et al.*, 1992; Cano *et al.*, 1997). Measurements of the tristimulus L*, a* and b* have given indication of the quality of snap beans (Pomeranz and Meloan, 1978; Francis, 1980; Clydesdale, 1991; Trail *et al.*, 1992; Mekwatanakarn and Richardson, 1994).

Postharvest life of snap bean can be further extended by the use of modified atmosphere packaging (MAP) (Buescher and Adams, 1979; Snodown, 1992; Costa *et al.* 1994). Likewise, quality attributes of bean pods were maintained by packaging in polymeric sealed films (Henderson and Buescher, 1977;Buescher and Adams, 1979; Trail *et al.*, 1992). The beneficial effects of film packaging can be explained by the modified atmosphere created inside the package (Ryal and Lipton, 1979; Wills *et al.*, 1989; Kader, 2002) as well as the resulting reduction in water loss (Ryal and Lipton, 1979; Hardenburg *et al.*, 1986; Snowdon, 1992; Cantwell and Kasmire, 2002). On the other hand, detrimental effects such as off-odor, off-flavor and pod injury have been reported by Anandaswamy and Iyengar, 1961; Henderson and Buescher, 1977 and Buescher and Adams, 1979.

The composition of the atmosphere inside the package depends on two processes - respiration of the commodity and permeation rate of the film (Zagory and Kader, 1988; Schlimm and Rooney, 1994; Saltveit, 1997; Kader, 2002). As more sophisticated types and combinations of films were developed, much research was devoted to relating film permeability to commodity tolerances in the belief that the modified atmosphere could be maintained in these small packages which could be beneficial to the market life of the commodity. Several films of different permeability to $O_2$, $CO_2$ and water vapor are now available for packaging fresh commodity (Ryal and Lipton, 1979;Wills *et al.*, 1989; Schlimm and Rooney, 1994; Kader, 2002).

Fresh green beans exported from Egypt is generally packed in different packages and film polymers, most of them were imported for this purpose. The amount of export from green beans during the year 2001-2002 was about 25 thousand ton (Ministry of Agriculture and land reclamation). So, there is a need to develop alternative Egyptian packages for beans. The purpose of this work was to study the possibility of replacing the different imported packages with an Egyptian film.

## MATERIALS AND METHODS

Green bean pods cv Bronco were harvested during 2002 and 2003 seasons from a local farm at Giza. The beans were brought to a packinghouse within 2 hours. Beans were inspected visually and defected and blemished pods were discarded. The rest was sorted and graded according to export criteria prior to packing.

### Experiment 1: The effects of different packages on the keeping quality of green beans.

The beans were packed in two different sizes (250 and 500 g) of perforated polypropylene bags and in 250g polyethylene bags (Egyptian film, provide with antifog agents) then sealed with a heat sealer, in the 4$^{th}$ treatment the pods were placed in trays (250g) and then overwrapped with polyvinylchloride (stretch film) and sealed with a hot plate. Twelve packages from each of treatment 1,3 and 4 and six packages from treatment 2 were packed in 3kg carton box. As for treatment 5, big polyethylene bags were used to line the 3kg box before placing the pods, the free ends were then over lapped (not sealed). In the last treatment the beans were packed in 3kg carton box (bulk loose). Thus, the six treatments were:

T1- Perforated polypropylene bags (sealed) ¼ kg.
T2- Perforated polypropylene bags (sealed) ½ kg.
T3- Polyethylene bags (sealed) ¼ kg.
T4- Stretch film (sealed) ¼ kg.
T5- Polyethylene lining 3 kg box.
T6- Bulk loose 3 kg box.

Except for the film used in the 3rd treatment which were specially prepared by Shouman plastic company for this investigation all the used three polymeric films were imported. All packages were transported in a refrigerated truck to the Horticulture Institute Laboratory. The samples were immediately weighted, labeled and stored at 7°C and 95% relative humidity. There were three replicates for every treatment as three boxes were randomly chosen at each evaluating date. The following characters were evaluated after 0, 5, 10 and 15 days of storage: weight loss, visual quality, firmness, off-odor, $O_2$, $CO_2$, color and dry matter. The measurement of such characters is discussed in the sequel.

Since an unacceptable odor and tissue damage have developed for green beans packaged in polyethylene sealed ¼ kg bags, which have otherwise produced superior results, a second experiment was warranted as described below.

**Experiment 2: The effects of macro-perforated modified atmosphere packaging, MAP, on the keeping quality of green beans.**

Packages of 250g beans were used as follows:

UNSP- Unpackaged on a Styrofoam plate.
NPP- Non-perforated polyethylene.
MPP2- Macro-perforated polyethylene with 2 pinholes
MPP4- Macro-perforated polyethylene with 4 pinholes.
MPP6- Macro-perforated polyethylene with 6 pinholes.
MPP8- Macro-perforated polyethylene with 8 pinholes.
MPP10- Macro-perforated polyethylene with 10 pinholes.
MPP12- Macro-perforated polyethylene with 12 pinholes.

Packages of each treatment were packed in carton boxes and immediately transported in a refrigerated truck to the Horticulture Institute. All samples were weighted, labeled and stored at 7°C and 95% relative humidity. Batches of samples were taken randomly at the beginning of the experiment and at 5 days intervals for evaluation. The following characters were determined.

**Weight loss** was measured as the percentage of loss from the initial weight (i.e., cumulative losses).

**Visual quality** was scored on a 9 to 1 scale, where 9 = Excellent, 7 = Good, 5 = Fair, 3 = Poor, 1 = Unusable (Watada and Morris, 1996; Jimenez *et al.*, 1998). The term "storage life" refers to the time required for the sample to deteriorate from a rating of 9 (field fresh) to 3 (poor) (Watada and Morris, 1996).

**Firmness and turgidity** were evaluated on a scale of 5 to 1, where 5 = Firm and turgid, 4 = Firm, 3 = Moderately firm, 2 = Limp and shrivel, 1 = More Limp and shrivel (Jimenez *et al.*, 1998).

**Color measurements.** Was evaluated objectively by Hunter Instrument DP-9000, which measures L*, a* and b*. L* measures color lightness (L* values are always positive where higher values are lighter color), a* measures color chromaticity that indicates color direction (where positive values of a* point to the red direction and negative values of a* point to the green direction) and b* is the second chromaticity measure that indicates color direction (where positive values of b* point to the yellow direction and negative values of b* point to the blue direction).

**Gas measurements.** The headspace atmosphere within the package was sampled using a sampling syringe inserted through a septum. The gas samples were analyzed for $O_2$ and $CO_2$ concentrations using a DualTrak model 902D Gas analyzer (Quantek Instruments, USA).

**Off-odor** was evaluated on a scale of 5 to 1, where 5 = Severe , 4 = Moderately severe, 3 = Moderate, 2 = Slight, 1 = None ( Kasmire *et al.*, 1974).

**Taste** was evaluated on a scale of 5 to 1, where 5 = Fully typical taste, 4 = Moderately full, 3 = Moderate, 2 = Slight, 1 = None (Kader, *et al.*, 1973).

**Dry matter** was estimated by drying 100 gm of fresh pods at 70°C until a constant weight was obtained. The percentage of dry matter was then calculated.

**Statistical analysis.** A completely randomized design with repeated measurements was employed. The entire experiment was repeated twice. Since the data exhibited similar patterns and trends, the analysis was run on the combined data. The treatment means were compared using the method of L.S.D. at the 5% level of significance (Snedecor and Cochran, 1989).

## RESULTS AND DISCUSSION

**The effects of different packaging on the keeping quality of green beans:**

**Weight loss.** The results for weight loss appear in Table 1 and are displayed in Figure 1. There was a significant increase in weight loss with prolonged storage for all packages (treatments). The least weight loss occurred for the poly ethylene (sealed) ¼ kg treatment (T3), with stretch film (T4) and poly ethylene lining (T5) second and third best, respectively. On the other hand, the perforated poly propylene treatments (T1 & T2) resulted in significantly higher weight losses, but still significantly better than the bulk loose package (T6), which proved to be the worst treatment. There was also a significant interaction between the treatments (packages) and the storage period. For instance, while the increase in weight loss, over the 15 days period, was slight, for poly ethylene sealed (T3), stretch film (T4) and poly ethylene lining (T5), a sharper increase was noticed for the perforated poly propylene treatments (T1 & T2) and the bulk loose package (T6).

**Table 1:The effect of different packages on Weight Loss, Visual Quality and Firmness of green beans during storage periods.**

| Storage period (days) | Treatments | Weight loss% | Visual quality | Firmness and turgidity |
|---|---|---|---|---|
| Initial | | 0.00 | 9.00 | 5.00 |
| 5 days storage | perforated poly propylene1/4 kg | 2.37 | 9.00 | 5.00 |
| | perforated poly propylene1/2 kg | 3.03 | 9.00 | 5.00 |
| | polyethylene (sealed) 1/4 kg | 0.12 | 9.00 | 5.00 |
| | stretch film 1/4 kg | 1.24 | 9.00 | 5.00 |
| | Polyethylene (lining) 3kg | 2.27 | 9.00 | 4.67 |
| | Bulk loose 3kg | 4.71 | 7.00 | 4.00 |
| | Mean | 2.29 | 8.67 | 4.78 |
| 10 days storage | perforated poly propylene1/4 kg | 7.29 | 5.00 | 3.00 |
| | perforated poly propylene1/2 kg | 5.80 | 5.67 | 4.00 |
| | Polyethylene (sealed) 1/4 kg | 0.34 | 9.00 | 5.00 |
| | stretch film 1/4 kg | 2.46 | 7.67 | 4.67 |
| | Polyethylene (lining) 3kg | 3.07 | 7.00 | 4.33 |
| | Bulk loose 3kg | 12.55 | 1.67 | 1.33 |
| | Mean | 5.25 | 6.00 | 3.72 |
| 15 days storage | perforated poly propylene1/4 kg | 14.56 | 1.00 | 1.00 |
| | perforated poly propylene1/2 kg | 11.57 | 1.67 | 1.33 |
| | Polyethylene (sealed) 1/4 kg | 0.52 | 7.00 | 4.33 |
| | stretch film 1/4 kg | 3.02 | 7.00 | 4.00 |
| | Polyethylene (lining) 3kg | 5.17 | 5.67 | 3.33 |
| | Bulk loose 3kg | 19.77 | 1.00 | 1.00 |
| | Mean | 9.10 | 3.89 | 2.50 |
| Treatment Means | perforated poly propylene1/4 kg | 8.07 | 5.00 | 3.00 |
| | perforated poly propylene1/2 kg | 6.80 | 5.44 | 3.44 |
| | Polyethylene (sealed) 1/4 kg | 0.33 | 8.33 | 4.78 |
| | stretch film 1/4 kg | 2.24 | 7.89 | 4.56 |
| | Polyethylene (lining) 3kg | 3.50 | 7.22 | 4.11 |
| | Bulk loose 3kg | 12.34 | 3.22 | 2.11 |
| LSD at 5% significance level for Treatment (T) | | 0.43 | 0.43 | 0.26 |
| LSD at 5% significance level for Storage (S) | | 0.35 | 0.35 | 0.21 |
| LSD at 5% significance level for T*S | | 0.86 | 0.87 | 0.51 |

**Visual Quality.** The results for visual quality appear in Table 2 and are displayed in Figure 2. There was a significant decrease in visual quality with prolonged storage for all packages (treatments). The best visual quality 3), and stretch film (T4), which are significantly better than poly ethylene lining (T5). On the other hand, after 10 days of storage, visual quality has deteriorated for the perforated poly propylene treatments (T1 & T2), which are, nonetheless, significantly better than the bulk loose package (T6). Also, there was a significant interaction between the treatments (packages) and the storage period. For instance, while the poly ethylene sealed (T3) package has maintained visual quality for at least 10 days, visual quality started deteriorating after 5 days, for the other packages, with sharp decrease for the bulk loose package (T6).

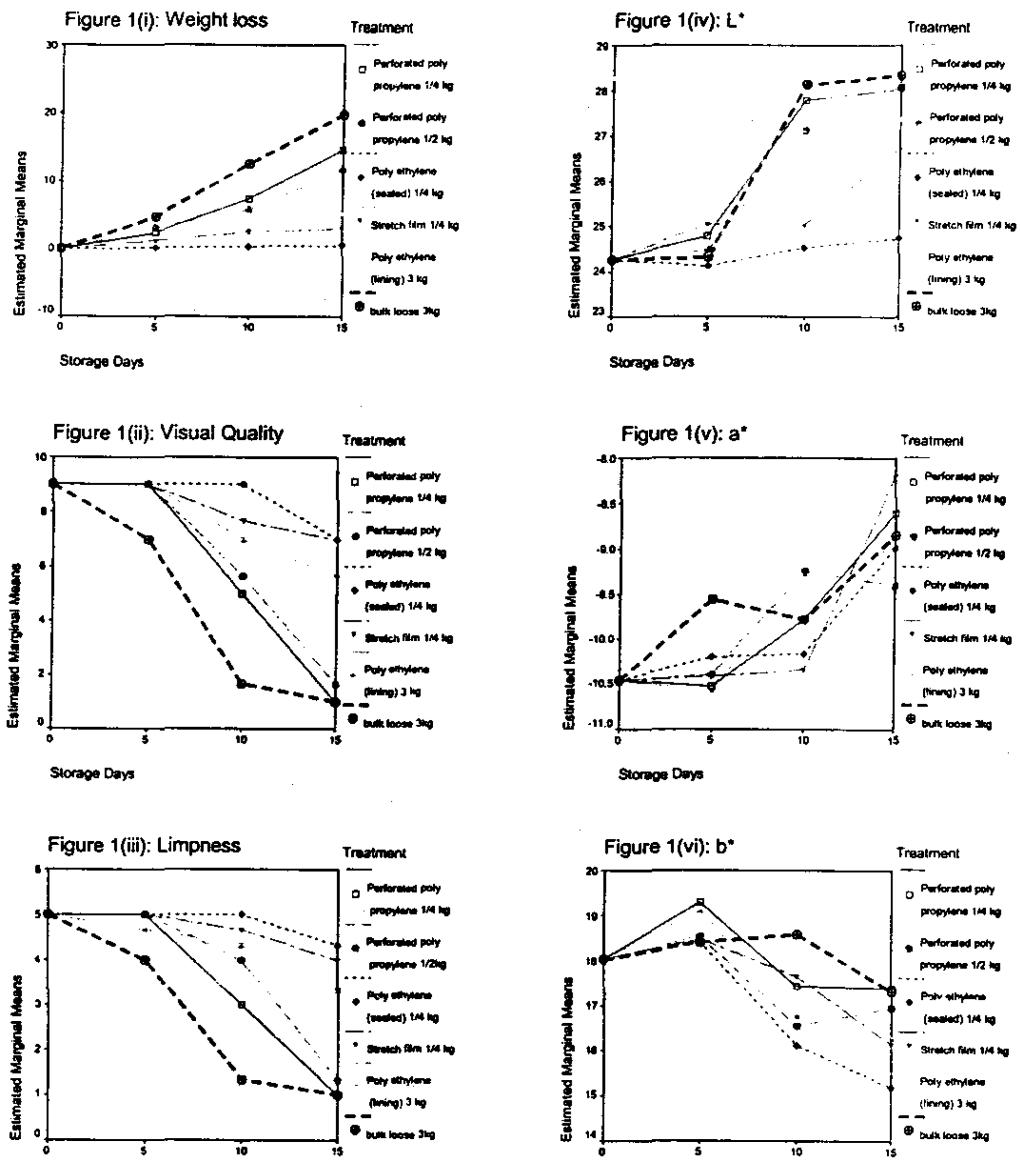


Figure 1 : Green Beans Quality and Color Characters by Storage Period and Treatment, Experiment 1.

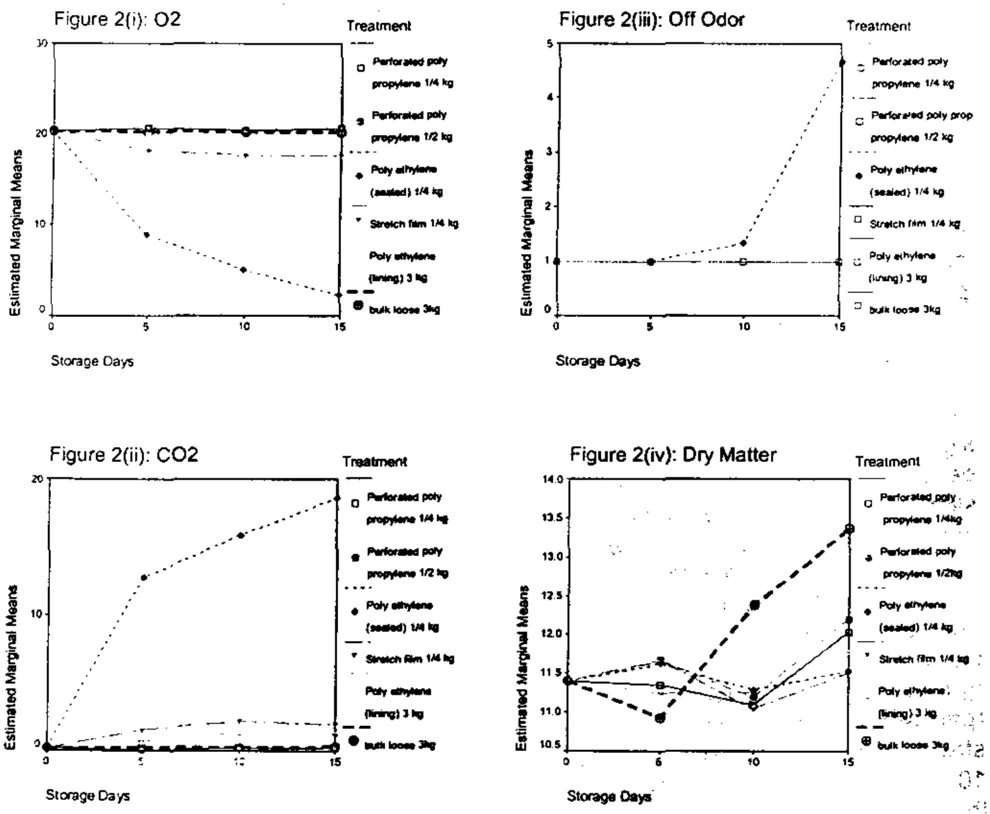


Figure 2: Green Beans Chemical Characters by Storage Period and Treatment, Experiment 1.

**Firmness and turgidity.** The results appear in Table 1 and are displayed in Figure 1 (iii) Data in Figure 3 show a significant decrease in firmness and turgidity with prolonged storage for all packages (treatments), except the poly ethylene (sealed) ¼ kg treatment (T3). The best results were those of the beans packed in poly ethylene (sealed) ¼ kg treatment (T3) where their pods were firm and crisp, followed by stretch film (T4), which is significantly better than poly ethylene lining (T5). On the other hand, after 5 days of storage, firmness and turgidity has sharply decreased for the perforated poly propylene treatments (T1 & T2). The bulk loose package (T6) produced the worst results. There was also a significant interaction between the treatments (packages) and the storage period. For instance, while the poly ethylene sealed (T3) package has maintained firmness and turgidity for at least 10 days, firmness and turgidity has decreased slightly, for stretch film (T4) and poly ethylene lining (T5), and sharply, for the other packages, especially after 10 days of storage.

**Color measurements.** The results for L*, which appear in Table 2 and are displayed in Figure 1(iv), show that color became significantly lighter with prolonged storage for all packages (treatments), except for the polyethylene (sealed) ¼ kg treatment (T3). The darkest color occurred for the polyethylene (sealed) ¼ kg treatment (T3), with stretch film (T4) second best. On the other hand, the perforated poly propylene treatments (T1 & T2) and the bulk loose package (T6), resulted in significantly lighter color. Also, there was a significant interaction between the treatments (packages) and the storage period. For instance, while the increase in L* over the 15 days period was slight for polyethylene sealed (T3), a sharper increase was noticed for the perforated poly propylene treatments (T1 & T2), the polyethylene lining (T5) and the bulk loose package (T6).

The results for a*, which appear in Table 2 and are displayed in Figure 1(v), show that the values of a* became less negative with prolonged storage for all packages (treatments), indicating degradation of chlorophyll (green color). There was also a significant interaction between the treatments (packages) and the storage period. Thus, for polyethylene sealed (T3) and stretch film (T4), there was a slight degradation of chlorophyll within the first 10 days, and a sharp degradation of chlorophyll after 10 days. In contrast, for the bulk loose package (T6), there was a sharp degradation of chlorophyll within the first 5 days, while for the perforated poly propylene treatments (T1 & T2) and the polyethylene lining (T5) the sharp degradation of chlorophyll occurred after 5 days.

The results for b*, which appear in Table 2 and are displayed in Figure 1(vi), show varying degrees of color in the yellow direction. However, the best (smallest) b* values occurred for polyethylene sealed (T3), while the worst (largest) occurred for the bulk loose package (T6).

**Gas measurement.** The results for $O_2$ appear in Table 3 and are displayed in Figure 2(i). Except for poly ethylene sealed (T3) and stretch film (T4), all packages have maintained average $O_2$ values in the range 19.93-20.67. For stretch film (T4), the average $O_2$ has decreased after 5 days of storage and stabilized from there on. For poly ethylene sealed (T3), there was a sharp decrease during the first 5 days of storage followed by a steady decline from there on.

**Table 2:The effect of different packages on Color Measurements of green beans during storage periods.**

| Storage period (days) | Treatments | Color (Hunter) | | |
|---|---|---|---|---|
| | | L* | a* | b* |
| Initial | | 24.26 | -10.46 | 18.03 |
| 5 days storage | Perforated poly propylene1/4 kg | 24.78 | -10.53 | 19.29 |
| | Perforated poly propylene1/2 kg | 24.47 | -10.39 | 18.55 |
| | Polyethylene (sealed) 1/4 kg | 24.12 | -10.20 | 18.43 |
| | Stretch film 1/4 kg | 25.05 | -10.41 | 18.49 |
| | Polyethylene (lining) 3kg | 24.60 | -10.58 | 19.11 |
| | Bulk loose 3kg | 24.31 | -9.56 | 18.42 |
| | Mean | 24.56 | -10.28 | 18.72 |
| 10 days storage | Perforated poly propylene1/4 kg | 27.79 | -9.78 | 17.44 |
| | Perforated poly propylene1/2 kg | 27.12 | -9.23 | 16.55 |
| | Polyethylene (sealed) 1/4 kg | 24.53 | -10.16 | 16.13 |
| | Stretch film 1/4 kg | 25.02 | -10.34 | 17.65 |
| | Polyethylene (lining) 3kg | 27.01 | -9.26 | 16.77 |
| | Bulk loose 3kg | 28.13 | -9.78 | 18.59 |
| | Mean | 26.60 | -9.76 | 17.19 |
| 15 days storage | Perforated poly propylene1/4 kg | 28.06 | -8.61 | 17.41 |
| | Perforated poly propylene1/2 kg | 28.09 | -9.40 | 16.96 |
| | Polyethylene (sealed) 1/4 kg | 24.74 | -8.99 | 15.18 |
| | Stretch film 1/4 kg | 26.71 | -8.20 | 16.15 |
| | Polyethylene (lining) 3kg | 27.37 | -8.98 | 16.27 |
| | Bulk loose 3kg | 28.34 | -8.85 | 17.32 |
| | Mean | 27.22 | -8.84 | 16.55 |
| Treatment Means | Perforated poly propylene1/4 kg | 26.88 | -9.64 | 18.04 |
| | Perforated poly propylene1/2 kg | 26.56 | -9.67 | 17.36 |
| | Polyethylene (sealed) 1/4 kg | 24.46 | -9.78 | 16.58 |
| | Stretch film 1/4 kg | 25.59 | -9.65 | 17.43 |
| | Polyethylene (lining) 3kg | 26.33 | -9.61 | 17.38 |
| | Bulk loose 3kg | 26.93 | -9.39 | 18.11 |
| LSD at 5% significance level for Treatment (T) | | 0.60 | 0.37 | 0.63 |
| LSD at 5% significance level for Storage (S) | | 0.49 | 0.30 | 0.52 |
| LSD at 5% significance level for T*S | | 1.21 | 0.74 | 1.27 |

The results for $CO_2$ appear in Table 3 and are displayed in Figure 2(ii). The perforated poly propylene packages (T1 & T2) and the bulk loose package (T6), have maintained average $CO_2$ values in the range 0.10-0.33. For poly ethylene lining (T5) and stretch film (T4), the average $CO_2$ has slightly increased, especially during the first 10 days. For poly ethylene sealed (T3), there was a sharp increase during the first 5 days of storage followed by a steady increase from there on.

**Off-odor.** The results for off-odor appear in Table 3 and are displayed in Figure 2(iii). Except for the poly ethylene (sealed) ¼ kg treatment (T3), all packages had no off-odor. The poly ethylene (sealed) ¼ kg treatment (T3) had no off-odor for 5 days. However, the average off-odor has slightly increased to 1.33 after 10 days, with a sharp increase to the unacceptable value of 4.67 after 15 days of storage.

**Table 3:The effect of different packages on $O_2$, $CO_2$, Off-Odor and Dry Matter of green beans during storage periods.**

| Storage-period (days) | Treatments | $O_2$ | $CO_2$ | Off- odor | Dry matter |
|---|---|---|---|---|---|
| Initial | | 20.27 | 0.20 | 1.00 | 11.40 |
| 5 days storage | perforated poly propylene1/4 kg | 20.60 | 0.10 | 1.00 | 11.35 |
| 5 days storage | perforated poly propylene1/2 kg | 20.67 | 0.20 | 1.00 | 11.66 |
| 5 days storage | polyethylene (sealed) 1/4 kg | 8.90 | 12.80 | 1.00 | 11.61 |
| 5 days storage | stretch film 1/4 kg | 18.20 | 1.57 | 1.00 | 11.66 |
| 5 days storage | polyethylene (lining) 3kg | 19.93 | 0.70 | 1.00 | 11.25 |
| 5 days storage | bulk loose 3kg | 20.23 | 0.23 | 1.00 | 10.93 |
| 5 days storage | Mean | 18.09 | 2.60 | 1.00 | 11.41 |
| 10 days storage | perforated poly propylene1/4 kg | 20.40 | 0.20 | 1.00 | 11.10 |
| 10 days storage | perforated poly propylene1/2 kg | 20.30 | 0.33 | 1.00 | 11.20 |
| 10 days storage | polyethylene (sealed) 1/4 kg | 5.10 | 15.90 | 1.33 | 11.29 |
| 10 days storage | stretch film 1/4 kg | 17.63 | 2.18 | 1.00 | 11.04 |
| 10 days storage | polyethylene (lining) 3kg | 20.30 | 1.33 | 1.00 | 11.25 |
| 10 days storage | bulk loose 3kg | 20.20 | 0.27 | 1.00 | 12.38 |
| 10 days storage | Mean | 17.32 | 3.37 | 1.06 | 11.38 |
| 15 days storage | perforated poly propylene1/4 kg | 20.63 | 0.20 | 1.00 | 12.03 |
| 15 days storage | perforated poly propylene1/2 kg | 20.63 | 0.20 | 1.00 | 12.20 |
| 15 days storage | polyethylene (sealed) 1/4 kg | 2.27 | 18.60 | 4.67 | 11.53 |
| 15 days storage | stretch film 1/4 kg | 17.60 | 1.97 | 1.00 | 11.51 |
| 15 days storage | polyethylene (lining) 3kg | 20.40 | 1.23 | 1.00 | 11.78 |
| 15 days storage | bulk loose 3kg | 20.20 | 0.30 | 1.00 | 13.37 |
| 15 days storage | Mean | 16.96 | 3.75 | 1.61 | 12.07 |
| Treatment Means | perforated poly propylene1/4 kg | 20.54 | 0.17 | 1.00 | 11.49 |
| Treatment Means | perforated poly propylene1/2 kg | 20.53 | 0.24 | 1.00 | 11.68 |
| Treatment Means | polyethylene (sealed) 1/4 kg | 5.42 | 15.77 | 2.33 | 11.48 |
| Treatment Means | stretch film 1/4 kg | 17.81 | 1.91 | 1.00 | 11.40 |
| Treatment Means | polyethylene (lining) 3kg | 20.21 | 1.09 | 1.00 | 11.43 |
| Treatment Means | bulk loose 3kg | 20.21 | 0.27 | 1.00 | 12.22 |
| LSD at 5% significance level for Treatment (T) | | 0.27 | 0.29 | 0.14 | 0.32 |
| LSD at 5% significance level for Storage (S) | | 0.22 | 0.24 | 0.11 | 0.26 |
| LSD at 5% significance level for T*S | | 0.53 | 0.59 | 0.27 | 0.64 |

**Dry matter**. The results for dry matter appear in Table 3 and are displayed in Figure 2(iv). For poly ethylene sealed (T3), stretch film (T4) and poly ethylene lining (T5), there were no significant differences in dry matter with prolonged storage. For the perforated poly propylene packages (T1 & T2), dry matter has significantly increased as storage reached 15 days. In contrast, there was a sharp significant increase in dry matter for the bulk loose package (T6) after 5 days of storage. Since dry matter percentage depends on fresh weight, it is most likely affected by factors that cause loss in tissue moisture content. So, this increase in dry matter percentage may be due to water loss.

**Correlation analysis.** The values of Pearson's pairwise correlation coefficient (r) between weight loss on one hand and visual quality, firmness and turgidity, L* and a*, on the other hand, were –0.937, -0.943, 0.792, and 0.527, respectively, which are fairly high in absolute values indicating fairly strong relationships and are highly significant at the 0.0001 level. Thus, while weight loss is inversely (negatively) related to visual quality and firmness, it is positively related to L* and a*. In contrast, visual quality is positively related to firmness (r=0.966), and inversely related to L* (r=-0.829) and a* (r=-0.592). Likewise, firmness is inversely related to L* (r=-0.812) and a* (r=-0.555), which are positively related to each other (r=0.565). As for b*, it is (moderately) positively related to visual quality (r=0.239), and negatively related to a* (r=-0.557). On the other hand, while off-odor is inversely related to $O_2$ (r=-0.706), it is positively related to $CO_2$ (r=0.695), which are inversely related to each other almost perfectly (r=-0.992).

The results show that beans quality attributes was influenced by packaging type and storage time. Various fruits and vegetables could benefit from the MAP produced within suitable sealed polymeric films by delaying both their physiological and pathological deterioration during storage, transit and marketing (Mekwatanakarn and Richardson, 1994; Beaudry, 1999; Kader, 2002). MAP is the use of the packaging film to alter the composition of the atmosphere in the package, if the packages are not flushed, this is considered to be passive MAP (Beaudry, 1999; Kader, 2002).

Film selection is an important component in obtaining the appropriate atmosphere. Packaging green beans in sealed polyethylene bags (T3) maintained the keeping quality of the pods much better than the other films used. Buescher and Adams (1979) came to similar results. The difference in the quality of the beans packed in polyethylene film (sealed), compared with PVC film, are due to the differences in their physical properties, e.g., less permeability to gases and water vapor as evidenced by gas concentration and water loss (Figures 2(i), 2(ii) and 1(i)).

Beans packaged in the perforated polypropylene packages were more limp and shrivel, less crisp, had lighter color and were of lower visual quality at the end of the storage period. This may be due to the ineffectiveness of the perforated packages in modifying the $CO_2$ and $O_2$ concentrations sufficiently to control respiration rates (Figures 2(i) and 2(ii)) and may also be due to loss of moisture as a result of the size and extent of the perforations. Limpness and crispness are textural attributes related to turgor or water content (Ryall and Lipton, 1979; Hardenburg *et al.*, 1986).

Likewise, polyethylene lining (T5) did not alter the gas composition or regulate loss of moisture sufficiently to aid quality retention at the end of the storage. Our results are in agreement with previous reports, which have shown that quality maintenance was affected by film type (Hardenburg, 1971; Buescher and Adams, 1979; Schlimm and Rooney, 1994; Kader, 2002).

The results reveal also that quality of pods was significantly reduced when kept unpackaged (bulk loose). This reduction in quality was reflected by lower color ratings, turgidity and general appearance. The pods reached an extremely wilted condition and were graded inedible at the end of storage time. These results confirm those of Hardenburg (1971).

Holding snap beans in polyethylene sealed package resulted in higher levels of $CO_2$ and lower levels of $O_2$ (passive modified atmosphere), which apparently was sufficient to prevent color changes, textural losses and development of defects during 10 days of storage. These results are in accordance with those of (Buescher and Adams, 1979; Trail *et al.*, 1992). The disadvantage of holding beans for longer periods (15 days or more) was the objectionable off odor and visible tissue damage, which is due to the extremely low $O_2$ levels and/or excessively high $CO_2$ levels or may be due to the interaction between $O_2$ and $CO_2$ in that elevated $CO_2$ levels make plant material more sensitive to low levels of $O_2$ (Beaudry, 1999). Henderson and Buescher (1977) stated that Oxygen levels of 5% or less caused off flavors in the canned product. They added that elevated $CO_2$ levels were not injurious to snap bean quality as long as $O_2$ was maintained at 10% or higher. On the other hand Anandaswany and Iyengar (1961) found that levels of 18.5 $CO_2$ produced off-flavor, however he failed to monitor $O_2$ levels and its likely that anoxia in the tissues actually caused the off-flavor.

**The effects of macro-perforated modified atmosphere packaging, MAP, on the keeping quality of green beans.**

**Weight loss.** The results for weight loss appear in Table 4 and are displayed in Figure 3(i). It turned out that there was a slight, but significant, increase in weight loss with prolonged storage. Further, except for the unpackaged treatment (UNSP) where the weight loss was huge, there were no significant differences among the other treatments.

**Table 4: The effect of macro-perforated modified atmosphere packaging, on Weight Loss, Visual Quality and Firmness of green beans during storage periods.**

| 0 | Treatments | Weight loss% | Visual quality | Firmness and turgidity |
|---|---|---|---|---|
| Initial | | 0.00 | 9.00 | 5.00 |
| 5 days storage | unpackaged on a styrofoam plate | 9.92 | 3.67 | 2.67 |
| | non-perforated polyethylene film | 0.11 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 2 pinholes | 0.05 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 4 pinholes | 0.06 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 6 pinholes | 0.15 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 8 pinholes | 0.16 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 10 pinholes | 0.16 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 12 pinholes | 0.14 | 9.00 | 5.00 |
| | Mean | 1.34 | 8.33 | 4.71 |
| 10 days storage | unpackaged on a styrofoam plate | 16.81 | 3.00 | 1.33 |
| | non-perforated polyethylene film | 0.44 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 2 pinholes | 0.32 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 4 pinholes | 0.31 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 6 pinholes | 0.37 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 8 pinholes | 0.34 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 10 pinholes | 0.32 | 9.00 | 5.00 |
| | macro-perforated polyethylene with 12 pinholes | 0.32 | 9.00 | 5.00 |
| | Mean | 2.41 | 8.25 | 4.54 |
| 15 days storage | unpackaged on a styrofoam plate | 30.21 | 1.00 | 1.00 |
| | non-perforated polyethylene film | 0.61 | 7.00 | 4.00 |
| | macro-perforated polyethylene with 2 pinholes | 0.46 | 7.00 | 4.00 |
| | macro-perforated polyethylene with 4 pinholes | 0.48 | 8.33 | 4.33 |
| | macro-perforated polyethylene with 6 pinholes | 0.55 | 8.33 | 4.67 |
| | macro-perforated polyethylene with 8 pinholes | 0.48 | 7.67 | 4.67 |
| | macro-perforated polyethylene with 10 pinholes | 0.46 | 8.33 | 4.67 |
| | macro-perforated polyethylene with 12 pinholes | 0.56 | 8.33 | 4.33 |
| | Mean | 4.23 | 7.00 | 3.96 |
| Treatment Means | unpackaged on a styrofoam plate | 18.98 | 2.56 | 1.67 |
| | non-perforated polyethylene film | 0.39 | 8.33 | 4.67 |
| | macro-perforated polyethylene with 2 pinholes | 0.28 | 8.33 | 4.67 |
| | macro-perforated polyethylene with 4 pinholes | 0.28 | 8.78 | 4.78 |
| | macro-perforated polyethylene with 6 pinholes | 0.36 | 8.78 | 4.89 |
| | macro-perforated polyethylene with 8 pinholes | 0.32 | 8.56 | 4.89 |
| | macro-perforated polyethylene with 10 pinholes | 0.31 | 8.78 | 4.89 |
| | macro-perforated polyethylene with 12 pinholes | 0.34 | 8.78 | 4.78 |
| LSD at 5% significance level for Treatment (T) | | 0.47 | 0.41 | 0.22 |
| LSD at 5% significance level for Storage (S) | | 0.33 | 0.29 | 0.16 |
| LSD at 5% significance level for T*S | | 0.29 | 0.25 | 0.13 |

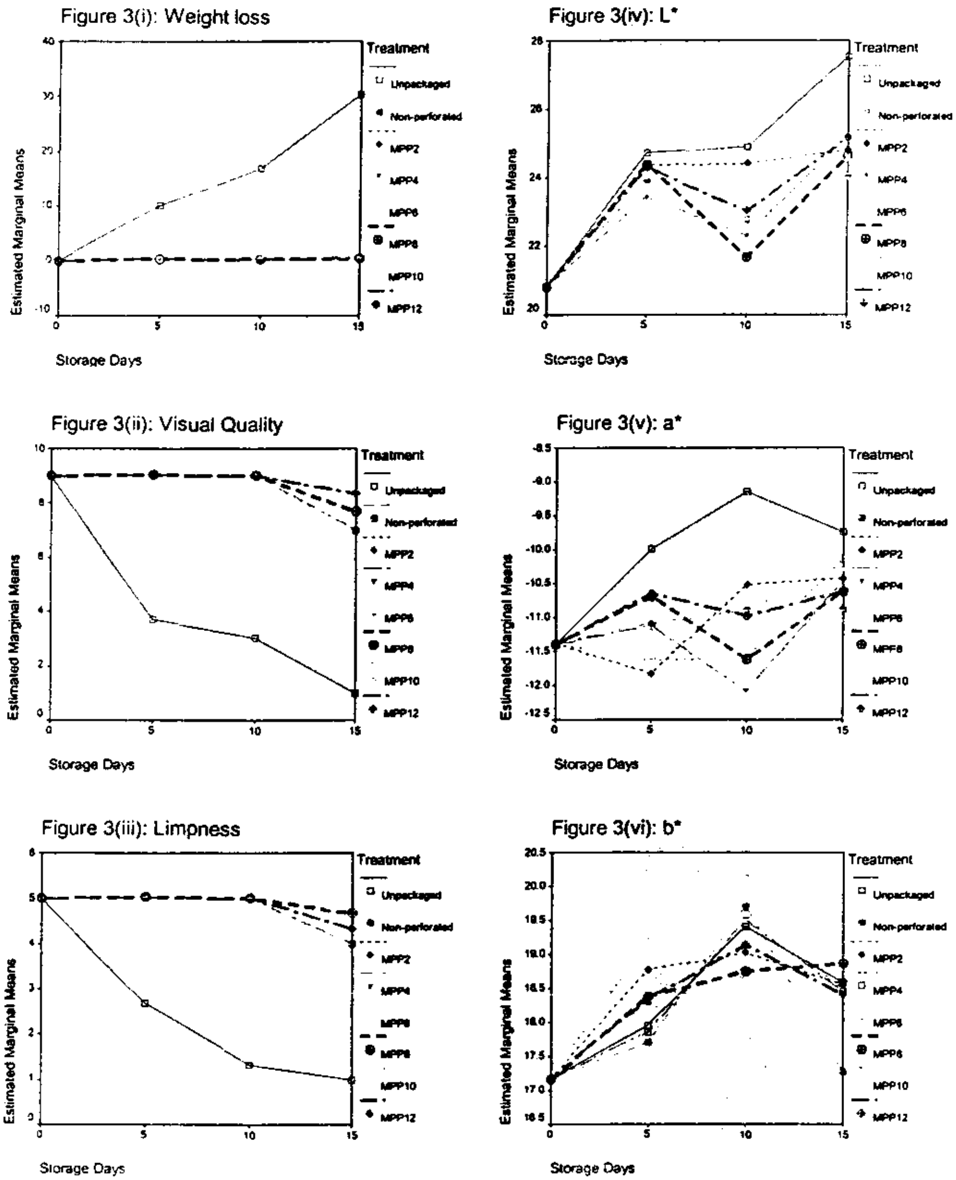


Figure 3: Green Beans Quality and Color Characters by Storage Period and Treatment, Experiment 2.

**Visual Quality.** The results for visual quality, which appear in Table 4 and are displayed in Figure 3(ii), show fast deterioration in the visual quality of unpackaged green beans (UNSP). The other packages maintained visual quality for 10 days. However, unless there were at least 4 pin holes in the macro-perforated polyethylene packaging, visual quality started to decrease as storage exceeded 10 days.

**Firmness and turgidity**. The results for firmness and turgidity, which appear in Table 4 and are displayed in Figure 3(iii), show fast decline in firmness and turgidity of unpackaged green beans (UNSP). The other packages maintained firmness and turgidity for 10 days. However, unless there were 6-10 pin holes in the macro-perforated polyethylene packaging, firmness and turgidity started to decrease as storage exceeded 10 days.

**Table 5: The effect of macro-perforated modified atmosphere packaging, on Color Measurements of green beans during storage periods.**

| Storage period (days) | Treatments | Color (Hunter) | | |
|---|---|---|---|---|
| | | L* | a* | b* |
| Initial | | 20.80 | -11.40 | 17.16 |
| 5 days storage | unpackaged on a styrofoam plate | 24.71 | -9.98 | 17.95 |
| | non-perforated polyethylene film | 23.87 | -11.10 | 17.69 |
| | macro-perforated polyethylene with 2 pinholes | 24.34 | -11.84 | 18.76 |
| | macro-perforated polyethylene with 4 pinholes | 23.40 | -11.13 | 17.85 |
| | macro-perforated polyethylene with 6 pinholes | 24.31 | -11.17 | 18.27 |
| | macro-perforated polyethylene with 8 pinholes | 24.36 | -10.70 | 18.37 |
| | macro-perforated polyethylene with 10 pinholes | 24.43 | -11.65 | 19.23 |
| | macro-perforated polyethylene with 12 pinholes | 24.28 | -10.66 | 18.34 |
| | Mean | 24.21 | -11.03 | 18.31 |
| 10 days storage | unpackaged on a styrofoam plate | 24.90 | -9.15 | 19.41 |
| | non-perforated polyethylene film | 22.75 | -10.89 | 19.71 |
| | macro-perforated polyethylene with 2 pinholes | 24.43 | -10.51 | 19.03 |
| | macro-perforated polyethylene with 4 pinholes | 22.31 | -12.07 | 19.51 |
| | macro-perforated polyethylene with 6 pinholes | 24.90 | -12.27 | 19.68 |
| | macro-perforated polyethylene with 8 pinholes | 21.67 | -11.61 | 18.75 |
| | macro-perforated polyethylene with 10 pinholes | 24.98 | -11.57 | 20.18 |
| | macro-perforated polyethylene with 12 pinholes | 23.02 | -10.98 | 19.14 |
| | Mean | 23.62 | -11.13 | 19.43 |
| 15 days storage | unpackaged on a styrofoam plate | 27.53 | -9.73 | 18.58 |
| | non-perforated polyethylene film | 24.03 | -10.89 | 17.28 |
| | macro-perforated polyethylene with 2 pinholes | 24.82 | -10.42 | 18.56 |
| | macro-perforated polyethylene with 4 pinholes | 25.22 | -10.46 | 18.46 |
| | macro-perforated polyethylene with 6 pinholes | 24.60 | -10.30 | 18.48 |
| | macro-perforated polyethylene with 8 pinholes | 24.63 | -10.61 | 18.86 |
| | macro-perforated polyethylene with 10 pinholes | 24.60 | -10.13 | 18.58 |
| | macro-perforated polyethylene with 12 pinholes | 25.19 | -10.61 | 18.41 |
| | Mean | 25.08 | -10.39 | 18.40 |
| Treatment Means | unpackaged on a styrofoam plate | 25.71 | -9.62 | 18.65 |
| | non-perforated polyethylene film | 23.55 | -10.96 | 18.23 |
| | macro-perforated polyethylene with 2 pinholes | 24.53 | -10.92 | 18.78 |
| | macro-perforated polyethylene with 4 pinholes | 23.64 | -11.22 | 18.60 |
| | macro-perforated polyethylene with 6 pinholes | 24.60 | -11.24 | 18.81 |
| | macro-perforated polyethylene with 8 pinholes | 23.55 | -10.96 | 16.66 |
| | macro-perforated polyethylene with 10 pinholes | 24.67 | -11.11 | 19.33 |
| | macro-perforated polyethylene with 12 pinholes | 24.16 | -10.75 | 18.63 |
| LSD at 5% significance level for Treatment (T) | | 1.24 | 0.63 | 0.83 |
| LSD at 5% significance level for Storage (S) | | 0.87 | 0.44 | 0.59 |
| LSD at 5% significance level for T*S | | 0.76 | 0.38 | 0.51 |

**Color measurements.** The results for L*, which appear in Table 5 and are displayed in Figure 3(iv), show that color became slightly lighter with prolonged storage for all packages (treatments), except for unpackaged green beans (UNSP), whose color became significantly lighter as storage exceeded 10 days. Similarly, the results for a*, which appear in Table 5 and are displayed in Figure 3(v), show that the values of a* for unpackaged green beans (UNSP) became much less negative with prolonged storage, indicating a significant degradation of chlorophyll (green color). The results for b*, which appear in Table 5 and are displayed in Figure 3(vi), show varying degrees of color in the yellow direction.

**Table 6: The effect of macro-perforated modified atmosphere packaging, on $O_2$, $CO_2$, Off Odor, Taste and Dry Matter of green beans during storage periods.**

| Storage period (days) | Treatments | $O_2$ | $CO_2$ | Off-odor | Taste | Dry matter |
|---|---|---|---|---|---|---|
| Initial | | 20.57 | 0.30 | 1.00 | 5.00 | 11.61 |
| 5 days storage | unpackaged on a styrofoam plate | 20.60 | 0.20 | 1.00 | 5.00 | 12.98 |
| | non-perforated polyethylene film | 11.10 | 11.70 | 1.00 | 5.00 | 11.58 |
| | macro-perforated polyethylene with 2 pinholes | 13.63 | 11.47 | 1.00 | 5.00 | 11.33 |
| | macro-perforated polyethylene with 4 pinholes | 16.07 | 6.80 | 1.00 | 5.00 | 11.73 |
| | macro-perforated polyethylene with 6 pinholes | 18.20 | 3.70 | 1.00 | 5.00 | 11.10 |
| | macro-perforated polyethylene with 8 pinholes | 19.10 | 2.20 | 1.00 | 5.00 | 12.09 |
| | macro-perforated polyethylene with 10 pinholes | 18.63 | 2.73 | 1.00 | 5.00 | 12.10 |
| | macro-perforated polyethylene with 12 pinholes | 18.70 | 2.73 | 1.00 | 5.00 | 12.20 |
| | Mean | 17.00 | 5.19 | 1.00 | 5.00 | 11.89 |
| 10 days storage | unpackaged on a Styrofoam plate | 20.60 | 0.20 | 1.00 | 3.33 | 13.04 |
| | non-perforated polyethylene film | 4.85 | 15.18 | 1.33 | 4.33 | 11.84 |
| | macro-perforated polyethylene with 2 pinholes | 14.57 | 13.87 | 1.00 | 4.33 | 11.20 |
| | macro-perforated polyethylene with 4 pinholes | 17.03 | 5.90 | 1.00 | 4.67 | 11.95 |
| | macro-perforated polyethylene with 6 pinholes | 17.77 | 5.07 | 1.00 | 5.00 | 11.60 |
| | macro-perforated polyethylene with 8 pinholes | 18.33 | 3.37 | 1.00 | 4.67 | 12.49 |
| | macro-perforated polyethylene with 10 pinholes | 17.93 | 3.03 | 1.00 | 5.00 | 11.78 |
| | macro-perforated polyethylene with 12 pinholes | 18.50 | 2.90 | 1.00 | 5.00 | 12.43 |
| | Mean | 16.20 | 6.19 | 1.04 | 4.54 | 12.04 |
| 15 days storage | unpackaged on a styrofoam plate | 20.53 | 0.30 | 1.00 | 2.33 | 14.81 |
| | non-perforated polyethylene film | 2.54 | 16.97 | 4.67 | 1.00 | 10.99 |
| | macro-perforated polyethylene with 2 pinholes | 3.60 | 15.60 | 2.00 | 3.33 | 11.93 |
| | macro-perforated polyethylene with 4 pinholes | 16.53 | 5.73 | 1.00 | 4.33 | 11.95 |
| | macro-perforated polyethylene with 6 pinholes | 18.17 | 4.93 | 1.00 | 4.00 | 12.30 |
| | macro-perforated polyethylene with 8 pinholes | 19.27 | 2.70 | 1.00 | 4.33 | 12.40 |
| | macro-perforated polyethylene with 10 pinholes | 18.50 | 2.97 | 1.00 | 4.33 | 11.92 |
| | macro-perforated polyethylene with 12 pinholes | 19.40 | 2.85 | 1.00 | 4.33 | 11.98 |
| | Mean | 14.82 | 6.51 | 1.58 | 3.50 | 12.29 |
| Treatment Means | unpackaged on a styrofoam plate | 20.58 | 0.23 | 1.00 | 3.56 | 13.61 |
| | non-perforated polyethylene film | 6.16 | 14.62 | 2.33 | 3.44 | 11.47 |
| | macro-perforated polyethylene with 2 pinholes | 10.60 | 13.64 | 1.33 | 4.22 | 11.49 |
| | macro-perforated polyethylene with 4 pinholes | 16.54 | 6.14 | 1.00 | 4.67 | 11.88 |
| | macro-perforated polyethylene with 6 pinholes | 18.04 | 4.57 | 1.00 | 4.67 | 11.67 |
| | macro-perforated polyethylene with 8 pinholes | 18.90 | 2.76 | 1.00 | 4.67 | 12.33 |
| | macro-perforated polyethylene with 10 pinholes | 18.36 | 2.91 | 1.00 | 4.78 | 11.93 |
| | macro-perforated polyethylene with 12 pinholes | 18.87 | 2.83 | 1.00 | 4.78 | 12.20 |
| LSD at 5% significance level for Treatment (T) | | 0.67 | 0.68 | 0.12 | 0.28 | 0.46 |
| LSD at 5% significance level for Storage (S) | | 0.47 | 0.48 | 0.08 | 0.20 | 0.33 |
| LSD at 5% significance level for T*S | | 0.41 | 0.42 | 0.07 | 0.17 | 0.28 |

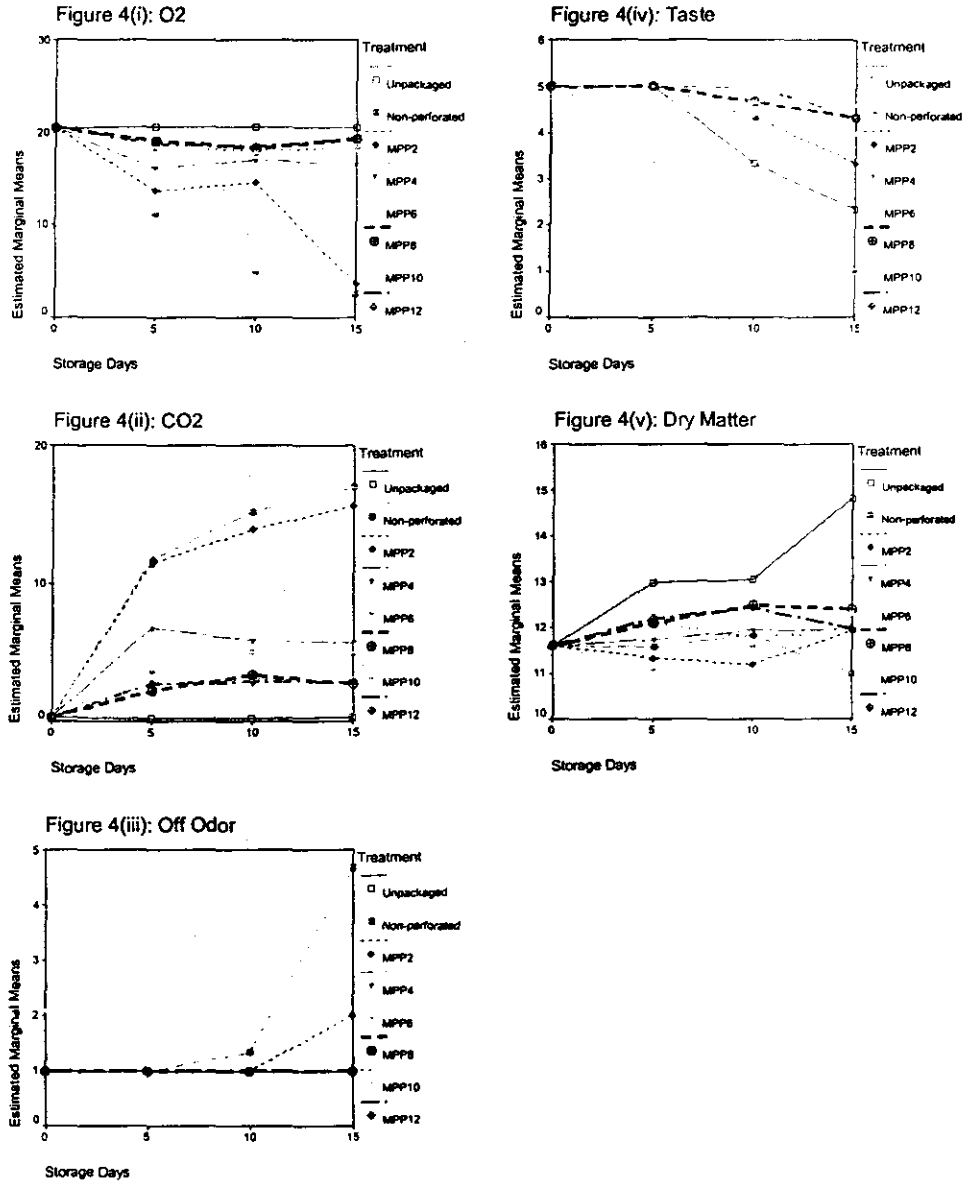


Figure 4: Green Beans Chemical Characters by Storage Period and Treatment, Experiment 2.

**Gas measurements.** The results for $O_2$, which appear in Table 6 and are displayed in Figure 4(i) show a sharp decline for non-perforated polyethylene (NPP) and macro-perforated polyethylene with 2 pin holes (MPP2). For all other packages, the decline was slight. The results for $CO_2$, which appear in Table 6 and are displayed in Figure 4(ii), were parallel in that the $CO_2$ concentrations have sharply increased for NPP and MPP2 compared with the other packages.

**Off-odor.** The results for off-odor appear in Table 6 and are displayed in Figure 4(iii). Except for non-perforated polyethylene (NPP) and macro-perforated polyethylene with 2 pin holes (MPP2), all other packages had no off-odor. In particular, off-odor has sharply increased to the unacceptable value of 4.67 after storing green beans in NPP for 15 days.

**Taste.** The results for taste, which appear in Table 6 and are displayed in Figure 4(iv), show that a minimum of 4 pin holes are required in macro-perforated polyethylene packaging to get at least a moderately full taste after 15 days of storage.

**Dry matter.** The results for dry matter appear in Table 6 and are displayed in Figure 4(v). It turned out that, except for the unpackaged treatment (UNSP) where dry matter was significantly higher, there were slight differences among the other treatments.

**Correlation analysis.** The values of Pearson's pairwise correlation coefficient (r) between weight loss on one hand and visual quality, firmness, L* and a*, on the other hand, were –0.913, -0.907, 0.393, and 0.441, respectively, which are fairly to moderately high in absolute values indicating fairly to moderately strong relationships and are highly significant at the

0.0001 level. Thus, while weight loss is inversely (negatively) related to visual quality and firmness, it is positively related to L* and a*. In contrast, visual quality is positively related to firmness (r=0.959), and inversely related to L* (r=-0.426) and a* (r=-0.518). Likewise, firmness is inversely related to L* (r=-0.443) and a* (r=-0.549), which are positively related to each other, though moderately (r=0.249). Also, b* is found to be positively related to L* (r=0.416). On the other hand, while off-odor is inversely related to taste (r=-0.704) and $O_2$ (r=-0.678), it is positively related to $CO_2$ (r=0.549). In contrast, taste is positively related to $O_2$ (r=-0.461) and inversely related to $CO_2$ (r=-0.402). The two gas concentrations $O_2$ and $CO_2$ are (strongly) inversely related (r=-0.907).

The results show that an objectionable off-odor and signs of tissue damage were detected for green beans bagged in NPP and MPP2 packages because when fresh fruits and vegetables were sealed inside plastic film packages of relatively low gas permeability, the $O_2$ concentration decreases while the $CO_2$ concentration increases as a consequence of tissue respiration. Eventually the $O_2$ concentration is reduced to a level that induces tissue anoxia while there is a concomitant increase in $CO_2$ which intensifies anaerobic environment in the package atmosphere. This results in anaerobic respiration in the produce, which rapidly destroys produce quality via tissue breakdown, accumulation of ethanol and acetaldehyde and development of off flavor and off odor. In anaerobic respiration, glucose is converted to pyruvate via the Embden Meyerchof Parnas (EMP) pathway. Pyruvate is then metabolized into acetaldehyde and ethanol (Wills *et al.*, 1989).

The results also show that these undesirable consequences of plastic film packaging were circumvented using films of numerous pin holes which demonstrate reasonably high permeability to $O_2$ and $CO_2$. These numerous pin holes will let in adequate $O_2$ to prevent anaerobic respiration and avoid $CO_2$ injury and can retard respiration and extend storage life. Our results are in agreement with those of Groeschel *et al.*(1966); Hardenburg (1971) and Schlimm and Rooney (1994).

As the use of numerous pin holes did not seem to have negatively affected green beans quality, it is recommended to use films of many pin holes since the holes may be blocked when the packages are packed in cartons for shipment. Further research is needed in this area.

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## عبوات البولى إيثيلين ذات الأجواء المعدلة تحافظ على جـودة قـرون الفاصوليـا أثناء التخزين

**راوية البسيونى ابراهيم البسيونى**
**قسم تداول الخضر – معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة**

تم دراسة تأثير العبوات المختلفة والتعبئة فى عبوات ذات أجـواء معدلـة علـى إحتفاظ قرون الفاصوليا بالجودة أثناء التخزين على درجة حرارة ٧م. ووجـد أن عبـوة البولى إيثيلين الجديدة المصنوعة بمصر قد إحتفظت بأفضل جودة مقارنة بالعبوات الأخرى المستوردة موضوع الدراسة. السلبية الوحيدة فى هذه العبوة الجديدة هى ظهور رائحة غير مقبولة عند تخزين الفاصوليا لمدة أطول من عشرة أيام. تليها فى الأفضلية العينات المعبئـة فى الإسترتش ثم العينات المبطنة بالبولى إيثيلين. وبينما كانت العينات المعبئة فى أكيـاس البولى بروبلين المثقب أقل فى الجودة من المعاملات السابقة فإنـها كـانت أفضـل مـن الفاصوليا الغير معبأة فى أكياس (سائبة) والتى كانت الأسوأ على الإطلاق.

ومن جهة أخرى ولتفادى ظهور الرائحة الغير مقبولة التى نتجـت عـن إطالـة التخزين فقد تم إجراء تجربة ثانية بتعبئة الفاصوليا فى عبوات البولى إيثيلين بعـد تثقيبـها بعدد مختلف من الثقوب (pin holes) ، وقد نجحت هذه العبوات فى المحافظة على جودة الفاصوليا نتيجة تعديل الأجواء داخلها بالإضافة إلى ميزتها فى الإحتفاظ برطوبـة نسـبية عالية ضرورية لتجنب ذبول الفاصوليا أثناء تداولها.