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Effect of Modified Atmosphere Packaging on French Beans (*Phaseolus vulgaris L.*) during Cold Storage

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ABSTRACT: *To maintain the quality and to enhance the shelf life of french beans a modified atmosphere system (MAP) with LDPE film of thickness 37.5 µm was selected with 0, 2 and 4 perforations of 1 mm diameter. Fresh french beans were stored at 5°C with a relative humidity of 95% for 21 days. In-pack gaseous composition, physiological loss in weight, colour, chlorophyll, and firmness were recorded at an interval of 3 days throughout the storage period. In the packages the minimum O_2 concentration of 1.45% and maximum CO_2 concentration of 14.00% was observed. Anaerobic conditions were observed in packages having 0 perforations. The control samples observed maximum physiological loss in weight, maximum change in colour, maximum loss of chlorophyll content and maximum loss in firmness. Overall it was found that LDPE 37.5µm package with 4 perforations was considered to be the best as regards to maintaining the quality of fresh french beans.*

KEYWORDS: *Modified atmosphere packaging, respiration rate, storage temperature, storage period, shelf life.*

I. INTRODUCTION

French bean is a highly perishable produce and the recommended storage conditions for best quality are low temperature, ideally 5 to 7.5°C, and a relative humidity of 95% [1]. Modified atmosphere packaging (MAP) has been found to be the best practice for the safe storage of french beans. During post-harvest handling, plant cells continue to respire. Snap beans have a very high respiration rate around 212 ml CO_2/Kg/hr [2]. Low oxygen and high carbon dioxide is beneficial to the french beans, however, when the amount of oxygen falls to less than 2 percent or less, fermentation instead of respiration occurs, resulting in breakdown of sugars to alcohol; and this alcohol causes unpleasant flavours in produce and also assist in premature aging [3]. Ethylene production rate observed in case of french beans is very low (0.05 µL kg^{-1} hr^{-1}). Ethylene exposure to more than 0.1 µL kg^{-1} hr^{-1} promotes chlorophyll loss, increases browning, and reduces storage life of beans by 30 to 50% at 5°C [4]. Weight loss in snap beans for 2 days were 1.3% at 2°C and 10°C and 3.5% at 21°C [2]. It was observed that moisture loss in cellophane package was insignificant during storage at 21°C, while unpackaged lots of beans lost considerable weight in 3 days [5].The present study was designed to analyse the quality of french beans packaged in LDPE 37.5 µm film with 0, 2 and 4 perforations in terms of in-pack gaseous composition, physiological loss in weight (PLW), colour, chlorophyll and firmness.

II. MATERIAL AND METHODS

2.1 Preparation of material

In this study, the french beans were procured as freshly harvested. The variety of french beans selected for the study named 'Falguni' was procured from Bharti Field Fresh India Pvt. Ltd., Laddowal, India. It is an export variety generally being exported to UK. This variety has good quality and yield. French beans were manually inspected for any kind of mechanical injury or some kind of diseased pods at the time of procurement.

2.2 Modified atmosphere packaging

On the basis of design of MAP, the low density polyethylene (LDPE) film of 37.5 µm thickness was chosen, and 0, 2 and 4 perforations of 1mm diameter were done in the packages. The french beans (both packed and loose) were stored in the walk-in-cold chamber having dimension 174 X 173 X 216 cm and at a temperature of 5°C ± 0.5°C with a relative humidity of 95%. Both temperature and relative humidity inside the chamber were precisely maintained at desired levels. French beans were put in a single layer in the plastic crates of 50 X 32 X 28 cm and crates were placed on the racks inside the chamber. Approximately 250 g of french beans were packaged in bags of size 10 inch x 8 inch. The effective area of the package was 0.0825 m^2, and this effective area of the package was mainly responsible for diffusion of respiratory gases (i.e. O_2 and CO_2) across the film barrier.

2.3 Measurements and observations

2.3.1 In-pack gaseous measurements

The gas composition was analysed with the help of gas analyser (PBI Dansensor; Checkpoint II Portable Gas Analyser, Ringsted, Denmark). Basically it was an oxygen (O_2) and carbon dioxide (CO_2) analyser used for the measurement inside food packages. The functional components of this instrument were oxygen sensor, LCD readout, internal sampling pump, and sampling probe. Sample was drawn through the probe and tubing and then simultaneously to the O_2 and CO_2 sensors when the pump was turned on. The O_2, CO_2 and remaining gases concentrations were read on the display screen.

2.3.2 Measurement of physiological loss in weight

Initial weight of the sample was noted at the time of keeping the sample for storage. Then subsequently weight was recorded on fixed intervals as per storage conditions, for the analysis. The PLW at each interval was calculated as:

$$PLW\ (\%) = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100 \qquad (1)$$

2.3.3 Measurement of colour

The basic purpose of colour measurement was to get an idea of comparative change in colour in different treatments with storage time. The colour of french beans was measured by Konica Minolta CR 10 Tristimulus Colorimeter (Konica Minolta, NJ, USA). 'L', 'a', and 'b' values were noted down and were then used for the calculation of total colour difference (ΔE) by using the undermentioned equation:

$$\Delta E = ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)^{1/2} \qquad (2)$$

where, $\Delta L = L_{sample} - L_{standard}$

$\Delta a = a_{sample} - a_{standard}$

$\Delta b = b_{sample} - b_{standard}$

2.3.4 Chlorophyll measurement

The chlorophyll was determined using procedure followed for tomatoes [6]. One gram of shredded french bean were homogenized with 10 ml of acetone and n-hexane (4:6); using a tissue homogenizer (Labco, New Delhi, India). This extraction was carried out till the whole tissue was extracted leaving white precipitate behind. The homogenized solution was allowed to stand for 1 min in a glass tube. One ml of supernatant was taken and was diluted with 9 ml of the extract solution. The resulting solution was analysed spectrophotometrically with the help of UV spectrophotometer (Make: Rayleigh; Model: UV-2601 UV/VIS Double Beam). Optical density of the solution was measured at different wavelengths namely 663 and 645 nm using acetone and n-hexane (4:6) as blank. Chlorophyll concentrations (µg ml^{-1}) were quantified using the following equations and then expressed as mg/100g fresh weight of sample:

$$\text{Chlorophyll } a = 0.999A_{663} - 0.989A_{645} \qquad (3)$$

$$\text{Chlorophyll } b = -0.328A_{663} + 1.77A_{645} \qquad (4)$$

Total chlorophyll content: Chlorophyll a + Chlorophyll b (5)

Where A_{663} and A_{645} are absorbance at 663 and 645 nm respectively.

2.3.5 Firmness measurement

The firmness of fresh and stored french beans was measured with the help of TA XT Plus texture analyser (Stable Micro Systems, Surrey, UK). This texture analyser consists of the basic components namely hardware (load cell) with platform to hold sample and moving head for holding the probe. Software Exponent Lite (Stable Micro Systems, Surrey, UK) was used for recording and calculating the results of the tests.

III. RESULTS AND DISCUSSION

3.1 In-pack gaseous composition

The gaseous composition in various samples of beans has been expressed in percent, which has shown in Table 1. Concentration of oxygen in packages decreased and that of carbon dioxide increased during first few days of the storage period, and thereafter a state of equilibrium was reached where respiration of the produce and the diffusion of these gases was counter balanced by the gaseous from the external atmosphere. In Fig. 1, it can be seen that that the LDPE 37.5 µm packages with 4 perforations had the highest oxygen concentration followed by packages having 2 perforations and least oxygen concentration was observed in non-perforated packages. The oxygen concentration was lowest in non-perforated 37.5µm film package. This particular trend was observed due to the fact that non-perforated film facilitated very little gas exchange as compared to perforated packages, and thus the oxygen concentration fell drastically leading to anaerobic conditions in the package.

Fig. 2 shows the change in carbon dioxide concentration with time. It was observed that that non-perforated LDPE 37.5 µm packages had the highest carbon dioxide concentration followed by packages having 2 perforations and the lowest in packages having 4 perforations. The reason for this kind of behaviour is that with increased number of perforations the the gas exchange increased and less accumulation *of carbon dioxide* took place. The data of in-pack gaseous composition was analysed with the help of SPSS (Statistical packages for social sciences) version 20 (IBM Corporation, NY, USA), and different superscripts were used to denote the mean values. The Tukey's test showed that all treatments were statistical significant at 5 % level of significance.

Table 1: In-pack gaseous composition (%) for 37.5 µm thickness LDPE film at low temperature storage conditions

Storage Period (days)	***In-pack gaseous composition***							
	O_2 Concentration (%)				***CO_2 Concentration (%)***			
	T0	***T2***	***T4***	***Mean***	***T0***	***T2***	***T4***	***Mean***
0	21.10	21.10	21.10	**21.10^{a}**	0.03	0.03	0.03	**0.03^{h}**
3	11.65	14.15	16.45	**14.08^{b}**	7.35	5.10	3.10	**5.18^{g}**
6	7.15	10.45	13.20	**10.27^{c}**	10.60	6.70	3.80	**7.03^{f}**
9	5.75	8.80	10.90	**8.48^{d}**	12.10	7.40	4.25	**7.92^{e}**
12	4.10	6.75	8.55	**6.47^{e}**	13.25	8.10	4.80	**8.72^{d}**
15	3.30	4.85	6.25	**4.80^{f}**	13.60	8.85	5.10	**9.18^{c}**
18	2.30	3.30	4.35	**3.32^{g}**	13.75	9.55	5.55	**9.62^{b}**
21	1.45	2.95	4.00	**2.80^{h}**	14.00	9.75	5.70	**9.82^{a}**
Mean	**7.10^{c}**	**9.04^{b}**	**10.60^{a}**		**10.59^{a}**	**6.94^{b}**	**4.04^{c}**	

3.2 Physiological loss in weight

The Physiological loss in weight in different samples of beans has been expressed in percent (Table 2). Weight loss of the french beans with LDPE packaged film was lower and linearly increased throughout storage. For unwrapped fruits the weight losses were higher, it could be due to senescence or more desiccation of french beans. It is quite evident from Fig. 3 that weight loss percentage increased at a steady rate with the duration of storage, and rate of weight loss was maximum (20.66 % on the 21st day) in control samples at ambient temperature. The rationale could be that unwrapped french beans lost moisture rapidly but the polyethylene packages restricted the moisture removal by creating a barrier to transpiration. The higher weight loss for unpackaged french beans than packaged ones in the present study is in conformity with the findings of previous researchers [7]. In case of LDPE 37.5 µm packages, as shown in Fig. 4, packages having 4 perforations recorded highest weight loss (0.65 % on the 21th day) followed by packages having 2 perforations (0.56 % on the 21th day) and then in non-perforated packages (0.46 % on the 21th day). This observed trend depicts that the physiological loss in weight increased as a result of increased number of perforations in the package. The physiological loss in weight for all the three treatments was found to be statistically significant at 5% level of significance.

Table 2: PLW (%) for 37.5 µm thickness LDPE film at low temperature storage conditions

Storage Period (days)	***PLW (%)***				
	Control	***T0***	***T2***	***T4***	***Mean***
0	0.00	0.00	0.00	0.00	**0.00**[h]
3	2.91	0.03	0.05	0.09	**0.77**[g]
6	5.19	0.06	0.18	0.27	**1.43**[f]
9	8.91	0.15	0.29	0.40	**2.44**[e]
12	10.85	0.26	0.39	0.47	**2.99**[d]
15	13.57	0.33	0.47	0.54	**3.73**[c]
18	15.89	0.43	0.53	0.61	**4.37**[b]
21	20.66	0.46	0.56	0.65	**5.58**[a]
Mean	**9.75**[a]	**0.22**[d]	**0.31**[c]	**0.38**[b]	

3.3 Colour

The increase in ΔE values signifies increase in colour change. Unwrapped french beans changed colour rapidly over the first 10 days of the storage and then at a slower rate over the next 11 days. French beans packaged in plastic films changed colour more slowly as compared to unwrapped beans. It could be seen from Fig. 5, that LDPE 37.5 µm non-perforated packages observed a maximum ΔE (7.47 on the 21stday) followed by packages having 2 perforations (6.64 on the 21stday) and the least value was observed in packages having 4 perforations (5.95 on the 21stday). The higher value of ΔE in case of 0 perforated packages signify that the maximum colour deterioration happened in case of 0 perforated packages because of the prevalence of anaerobic conditions. Tukey's test showed that ΔE for various treatments were statistically significant at 5% level of significance.

Table 3: Colour (ΔE) for 37.5 µm thickness LDPE film at low temperature storage conditions

Storage Period (days)	**Colour (ΔE)**				
	Control	**T0**	**T2**	**T4**	**Mean**
0	0.00	0.00	0.00	0.00	**0.00**[h]
3	6.94	2.65	3.90	3.34	**4.21**[g]
6	10.40	4.71	4.41	4.81	**6.08**[f]
9	10.68	5.90	4.84	4.89	**6.58**[e]
12	11.76	6.21	5.54	5.14	**7.16**[d]
15	12.47	6.95	5.85	5.64	**7.73**[c]
18	13.45	7.23	6.16	5.80	**8.16**[b]
21	14.00	7.47	6.64	5.95	**8.52**[a]
Mean	**9.96**[a]	**5.14**[b]	**4.67**[c]	**4.45**[d]	

The increase in 'a' values at ambient conditions were observed to be maximum for control samples which indicated that the control samples observed maximum loss of greenness. In case of 37.5 µm LDPE packages, the non-perforated packages observed anaerobic conditions which led to loss of colour and hence more increase in 'a' value as compared to other treatments. Fig. 6 shows that non-perforated packages of LDPE 37.5 µm observed a maximum increase in 'a' value followed by packages having 2 perforations and the minimum value was observed in packages having 4 perforations.

3.4 Chlorophyll

The chlorophyll content of the french beans was calculated and expressed as total chlorophyll (mg/100 g). The chlorophyll for all the treatments was found to be statistically significant at 5% level of significance. It is evident from Fig. 7 that LDPE 37.5 µm packages having 4 perforations retained maximum total chlorophyll followed by packages having 2 perforations and the minimum value was observed in non-perforated packages. The non-perforated packages observed maximum loss in chlorophyll because of the anaerobic conditions.

Table 4: Chlorophyll content for 37.5 µm thickness LDPE film at low temperature storage conditions

Storage Period (days)	**Chlorophyll Content (mg/100g)**				
	Control	**T0**	**T2**	**T4**	**Mean**
0	103.01	103.01	103.01	103.01	**103.01[a]**
3	88.59	99.13	98.84	94.67	**95.31[b]**
6	72.12	93.72	90.76	86.95	**85.89[c]**
9	60.73	85.40	84.46	80.25	**77.71[d]**
12	50.34	75.71	77.82	75.04	**69.73[e]**
15	46.96	66.38	74.41	73.35	**65.28[f]**
18	43.31	60.12	71.75	72.14	**61.83[g]**
21	41.56	58.64	70.50	71.90	**60.65[h]**
Mean	**63.33[d]**	**80.26[c]**	**83.94[a]**	**82.16[b]**	

3.5 Firmness

In case of LDPE 37.5 µm film packages, as shown in Fig. 8, package having 4 perforations recorded highest firmness followed by package having 2 perforations and least firmness was recorded in non-perforated packages. It was observed that LDPE 37.5 µm packages having 4 perforations were found to be the best in retaining the firmness of the french beans. The possible explanation of this trend could be that, the gaseous concentration in these samples was in the desired range at the end of the storage period. The firmness for all the treatments was found to be statistically significant at 5% level of significance using the Tukey's test.

Table 5: Firmness for 37.5 µm thickness LDPE film at low temperature storage conditions

Storage Period (days)	***Firmness (kg)***				
	Control	***T0***	***T2***	***T4***	***Mean***
0	13.15	13.15	13.15	13.15	**13.15[a]**
3	11.42	11.89	12.25	12.12	**11.92[b]**
6	9.19	10.34	11.78	11.15	**10.62[c]**
9	8.16	9.46	11.56	10.73	**9.98[d]**
12	6.98	8.56	10.35	10.30	**9.05[e]**
15	6.13	7.39	9.76	9.75	**8.26[f]**
18	5.67	7.10	9.53	9.65	**7.99[g]**
21	5.50	6.78	9.37	9.55	**7.80[h]**
Mean	**8.27[d]**	**9.33[c]**	**10.97[a]**	**10.80[b]**	

IV. CONCLUSION

MAP maintained the quality of fresh french beans. Samples stored at atmosphere of 4% O_2 and 5.7% CO_2 helped in keeping fresh quality of french beans for 21 days at 5°C. This period could be considered as appropriate for the transportation, distribution and retail chain needs of the fresh french beans. Overall it was observed that 37.5 µm LDPE package having 4 perforations was found to be the best as regards to safe storage of french beans.

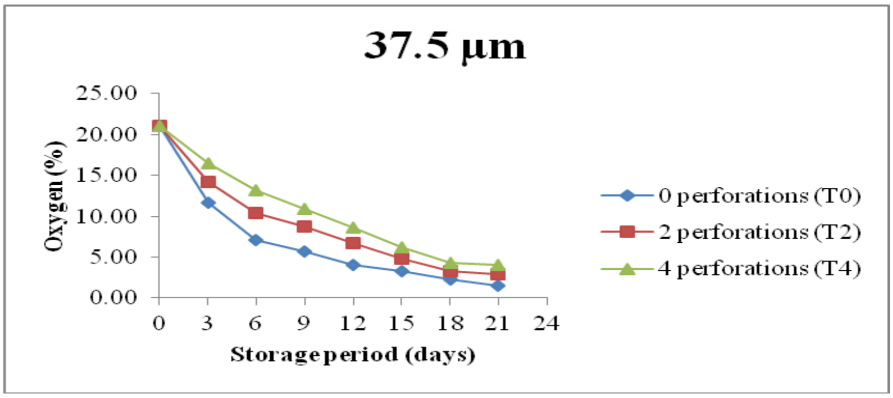

Figure 1: Oxygen concentration (%) for 37.5 µm thickness LDPE film at low temperature storage conditions

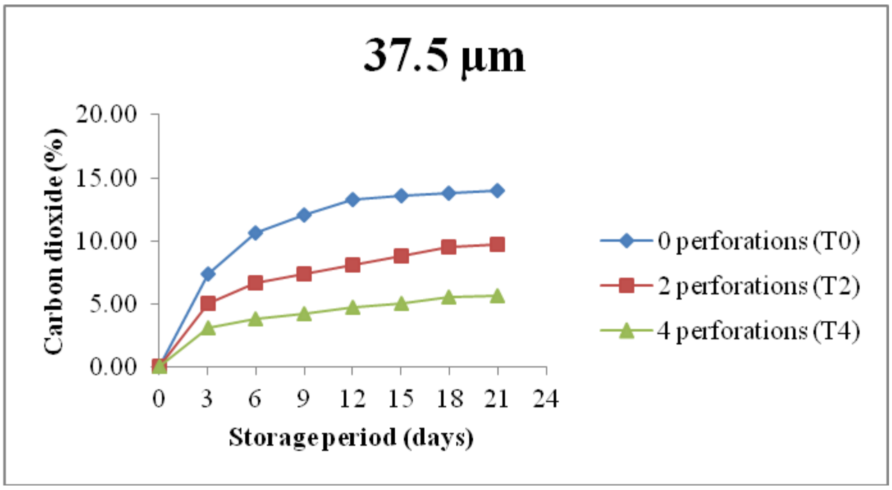

Figure 2: Carbon dioxide concentration (%) for 37.5 µm thickness LDPE film at low temperature storage conditions

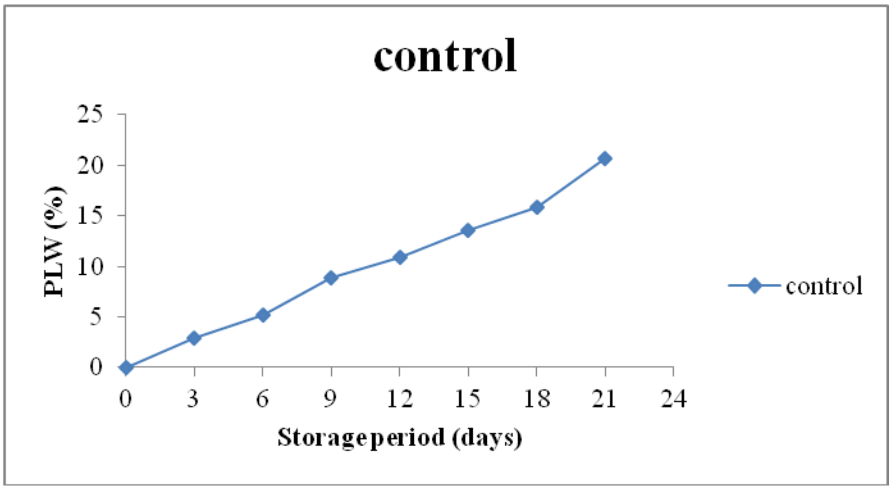

Figure 3: PLW (%) for control samples at low temperature storage conditions

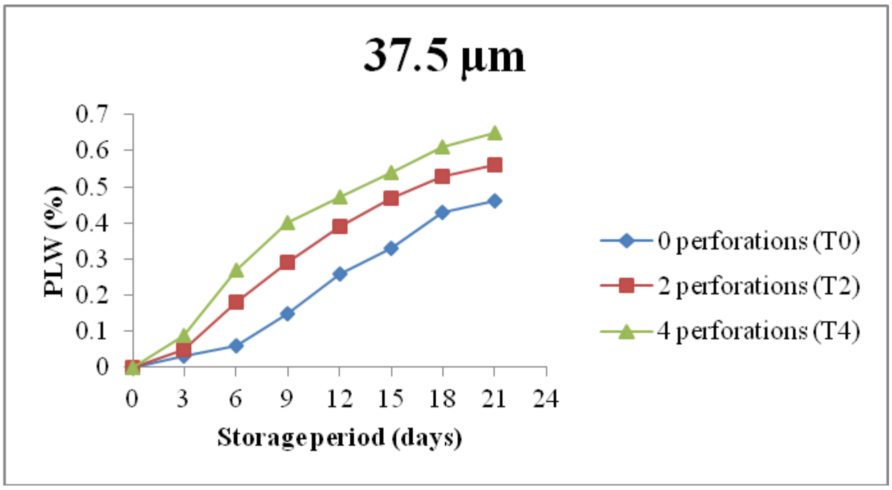

Figure 4: PLW (%) for 37.5 µm thickness LDPE film under low temperature storage conditions

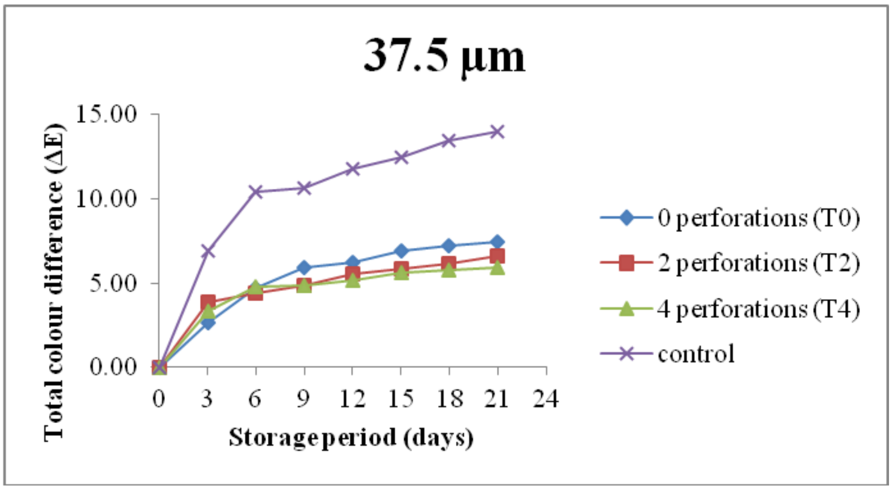

Figure 5: 'ΔE' values for 37.5 µm thickness LDPE film at low temperature storage conditions

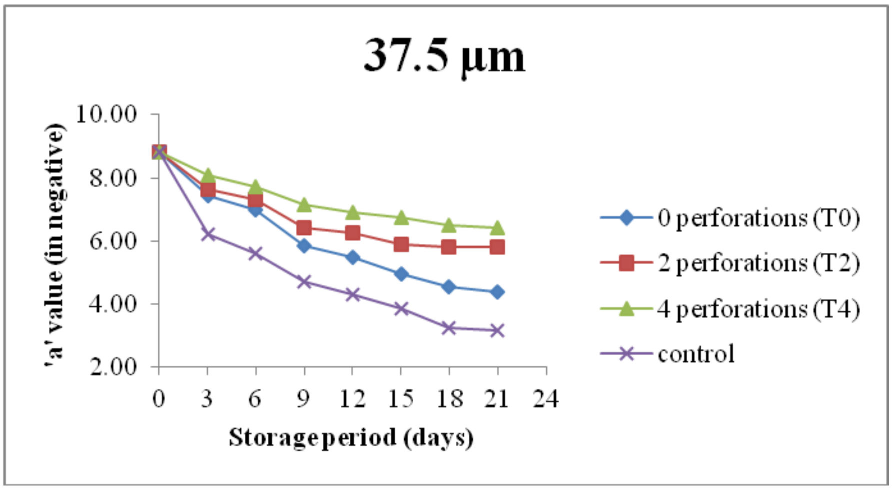

Figure 6: 'a' values for 37.5 µm thickness LDPE film at low temperature storage conditions

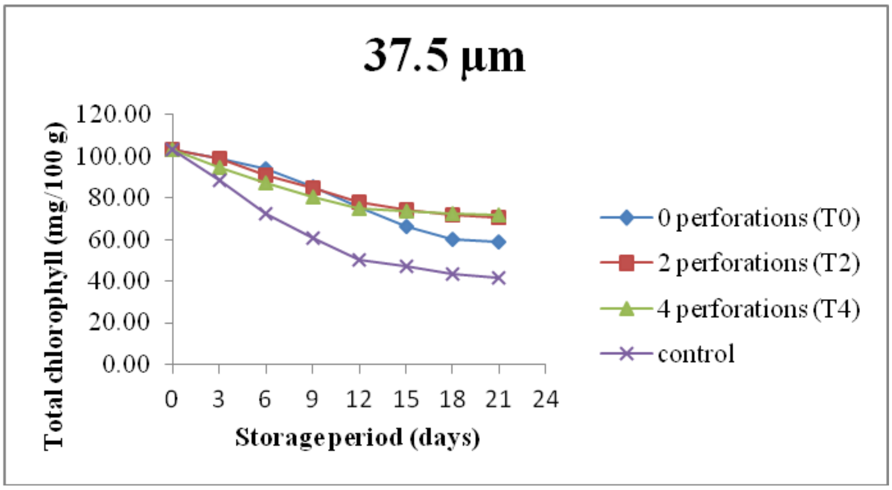

Figure 7: Total chlorophyll content (mg/100 g) for 37.5 µm thickness LDPE film at low temperature storage conditions

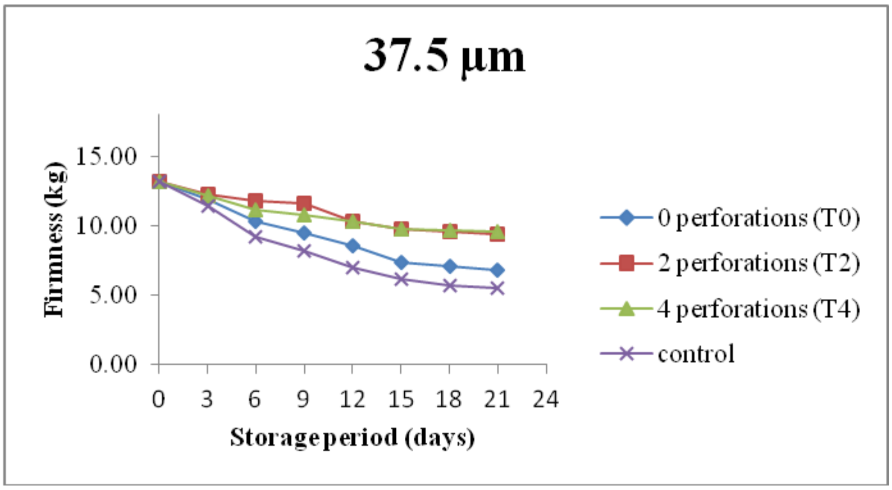

Figure 8: Firmness (kg) for 37.5 µm thickness LDPE film at low temperature storage

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