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Evaluation of Packaging Materials for Shelf-Life Extension of *Assam* Lemon (*Citrus limon* Burm.) During Storage

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ABSTRACT

The experiment was conducted to evaluate the suitable packaging materials for shelf life extension of *Assam* lemon fruit at ambient condition. During storage, physico-chemical changes were determined at 7, 21, 35, 56 and 77 days of storage using perforated (2, 6 and 10 pin hole) and non-perforated PP (Polypropylene), LDPE (Low density polyethylene) and LDHM (Low density high molecular weight), and control. The rate of change (Total soluble solids, titratable acidity, ascorbic acid and chlorophyll) in packed fruit was comparatively slower as compared to that of control fruits. The present study revealed that packaging of fruits in perforated 2 pin hole PP had distinct advantages over control and other packaging materials in respect of shelf life extension besides retention of quality and nutritional value of the fruits. *Assam* lemon can be stored up to 21 ±1.00 days only in ambient conditions whereas extension of shelf life up to 77 ±1.41 days is possible by packing the fruits in perforated 2 pin hole PP and this could be suggested for obtaining the optimum and desirable qualities of the fruits with a better shelf life.

Keywords *Assam* lemon, Packaging, Physico-chemical properties, Shelf life.

INTRODUCTION

Citrus fruits are highly regarded for their nutritive value and economic significance. They are not only refreshing to eat, but also provide vitamins, minerals, alkaline salts and many others essential substances which are required for human health. Being a non-climacteric fruit, judging its maturity at harvest is an important factor affecting the quality perception and the rate of change of quality during post harvest handling. *Assam* lemon fruits are harvested at 120-130 days after fruit set (Mukhim *et al.* 2015). Fruits picked at the wrong stage of maturity may develop physiological disorders in storage and may exhibit poor dessert quality. Storage of citrus fruits for extended period is very essential for the proper utilization of the fruit during glut season. Inadequate packaging leads to post-harvest losses and eventually reduces the shelf life. In contrast, proper packaging provides protection without deteriorating the qualities and appearance, reduction in moisture loss, prolonged shelf

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life with increased market acceptability. The use of plastic film in extending shelf life of fruits is growing in importance due to its convenient throughout the chain of handling from producer to consumer. Many studies have revealed that plastics films in the form of film wrapping, HDPE unipacking as well as LDPE bags provided a cost effective methods for extension of shelf life of citrus fruits. Therefore the study is being carried out with an objective to determine the storage life of *Assam* lemon at ambient conditions using different packaging materials.

MATERIALS AND METHODS

The experiment was conducted at the Post Harvest Technology Laboratory of the Division of Horticulture, ICAR Research Complex for NEH Region, Barapani, Umiam 793103, Meghalaya, during the year 2008-2009. *Assam* lemon fruits were procured from the Experimental Farm of the Division of Agro-forestry, ICAR (RC), Barapani, Umiam. Care was taken to harvest the fruits at physiologically matured and ripened stage when the rind color changes to light green with smooth skin and the fruits contain maximum juice. The fruits were washed thoroughly with tap water followed by distilled water and kept in a perforated plastic tray for drying (2-3 h under ambient condition) prior to packaging. Fruits (500-550 g) containing 3-5numbers having average fruit weight of 108-113 g were packed in each perforated (2, 6 and 10 pin holes of 1 mm diameter) and non-perforated (20×15 cm^2) polybags of different thickness (PP 100 gauge, LDPE 200 gauge and LDHM 100 gauge) with treatments viz. Non-perforated PP (NP-PP), Perforated 2 pin hole PP (P2-PP), Perforated 6 pin hole PP (P6-PP), Perforated 10 pin hole PP (P10-PP), Non-perforated LDPE (NP-LDPE), Perforated 2 pin hole LDPE (P2-LDPE), Perforated 6 pin hole LDPE (P6-LDPE), Perforated 10 pin hole LDPE (P10-LDPE), Non-perforated LDHM (NP-LDHM), Perforated 2 pin hole LDHM (P2-LDHM), Perforated 6 pin hole LDHM (P6-LDHM), Perforated 10 pin hole LDHM (P10-LDHM) and control. The total surface area of each film bag was 300 cm^2, with film permeability of 1,500, 3,000, and 3,500 cc/m^2/mil/day at 1 atm for O_2 and 6,000, 11,000, and 8,500 cc/m^2/mil/day at 1 atm for CO_2 respectively for all non perforated PP 100 gauge, LDPE 200 gauge and LDHM 100 gauge packaging materials. The packets were then sealed with the help of a sealing machine and kept under ambient condition (25 ± 2°C and 65 ± 5% RH) for observation. Fruits for control were kept in open condition. Each treatment was replicated five times and then was analyzed at 7, 21, 35, 56 and 77 days of storage.

Physiological loss in weight (PLW) : Per cent physiological losses in weight (PLW) were calculated by using the formula described by Srivastava and Tandon (1968).

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

Decay loss : Decay loss were recorded at a periodical interval and the cumulative decay loss were calculated (on weight basis) using the following formula.

$$\text{Decay loss (\%)} = \frac{\text{Weight of the infected fruit}}{\text{Total weight}} \times 100$$

Fruit color characteristics : The fruit peel colors were measured using a Hunter Lab Color Quest XE colorimeter (McGuire 1992). Color measurements were expressed in terms of value L, a, b and color difference (ΔE), where, L is a measure of lightness on a scale ranging from 0 (black) to 100 (white), +a denotes redness, -a indicates greenness; +b denotes yellowness and –b indicates blueness respectively. The hunter color difference was calculated from the equation, $\Delta E = (\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$ using initial color values of *Assam* lemon as reference.

Fruit firmness measurement : The textural property of the fruits in term of firmness were measured using a Stable Micro System TA-XT-plus texture analyzer (Texture Technologies Corp, UK) fitted with a 35 mm cylindrical aluminium probe. Firmness value was considered as mean peak compression force and expressed in kg. The studies were conducted at a pre-test speed of 4 mm/sec, test speed of 4 mm/sec, post-test speed of 10 mm/sec, distance of 25 mm and trigger force of 10 g.

Juice content : Fruit juice content were measured

with the help of graduated cylinder and then expressed into percentage.

Chemical characteristics : The fruit quality parameters were studied in terms of total soluble solids (°Brix), titratable acidity (%) and ascorbic acid (mg/100 g). Total soluble solid (TSS) was determined with the help of digital refractometer. Acidity was estimated by titrating against 0.1N NaOH using phenolphthalein as indicator. Acidity as citric acid was calculated and expressed in to percentage (AOAC 1995).

Ascorbic acid content was determined by using 2, 6-Dichlorophenol-indophenol dye method of Freed (1966). 5 g of the sample was grounded with about 25 ml of 4% oxalic acid and filtered through Whatman no. 4 filter paper. The filtrate was collected in a 50 ml volumetric flask and the volume was made up with 4% oxalic acid and titrated against the standard dye to a pink point. The amount of ascorbic acid was calculated using the following formula and expressed as mg/100 g.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume make up} \times 100}{\text{Aliquot} \times \text{Weight or volume of the sample taken for estimation}}$$

Chlorophyll : Total chlorophyll content of the fruit was determined by using the colorimetric method of Singh (1977). 2 g of finely cut and well mixed representative sample was placed in a clean mortar. The tissue was grounded to a fine pulp by adding 20 ml of 80% acetone. Then the material was centrifuged (5000 rpm for 5minutes) and supernatant was transferred to a 100 ml volumetric flask. This procedure was repeated until the residue was colorless. The volume was then made up to 100 ml with 80% acetone. The optical density at 645 and 663 nm was recorded for each sample and the total chlorophyll was estimated by the following formula.

$$\text{Total chlorophyll (mg/ 100 g)} = \frac{20.2\,(\text{OD at } 645 \text{ nm}) + 8.02\,(\text{OD at } 663 \text{ nm}) \times V}{100 \times W}$$

Where, OD = Optical density, V= Volume of the extractant (ml), W = Weight of the sample (g)

Shelf life : Shelf life of Assam lemon fruit was determined by constituting a sensory panel of five members team of semi trained male Scientists in the age group of 35–45 years of ICAR Research Complex, Umiam, Meghalaya. The visual and textural qualities were observed and scores were given as per the scales given by Bhowmick and Pan (1992). For visual quality,9 = Excellent, 7 = Very good, 5 = Good, limit of marketability, 3 = Fair, limit of usability and 1 = Poor, inedible. For texture, 5 = Fresh, 3 = Moderately fresh, limit of marketability and 1 = Soft. Whenever the fruits reached the score representing the limit of marketability, its shelf life was declared terminated.

Statistical analysis : Results were analyzed by analysis of variance (ANOVA) and standard error (SE) of mean was also calculated for presentation in tables. Significance of specific mean difference was determined by calculating the critical difference at 5% level.

$$\text{Critical difference (CD)} = \text{SEd } (\pm) \times \text{'t'}$$

Where, 't' is the tabulated value of 't' at 5% level of significance at error degrees of freedom.

RESULTS AND DISCUSSION

Cumulative PLW : *Assam* lemon fruits showed gradual increase in PLW during storage irrespective of treatments. The maximum PLW (40.16 %) was recorded in control fruits at 35 days of storage. The probable reason for increase in PLW during storage was due to evapo-transpiration, respiration and degradation processes. However, the minimum PLW (2.06%) at the end of the storage was recorded in NP-LDHM packed fruits, kept at ambient condition up to 77 days followed by P2- PP (2.55%) (Table 1). The loss in weight could be attributed to creation of semi-permeable barrier around the fruit by the plastic film and water saturated atmosphere inside the packaging materials. Similar reduction in PLW of sealed packed pomegranate-fruit with LDPE film was reported by Jena *et al.* (2019).

Table 1. Effect of packaging materials on physiological loss of weight (%) and decay loss (%) of *Assam* lemon during storage. Initial value: PLW= 0%, Decay loss= 0%, DAS= Days after storage and NS= Non-significant.

Treatments	Physiological loss of weight %					Decay loss %				
	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS
NP-PP	0.15	0.42	-	-	-	23.87	63.06	87.30	100.00	-
P2-PP	0.20	1.05	1.82	1.85	2.55	-	-	-	-	27.73
P6-PP	0.27	1.05	1.95	3.59	-	-	-	44.17	68.55	64.23
P10-PP	0.57	1.77	3.62	5.10	6.81	-	-	-	28.52	43.00
NP-LDPE	0.15	0.63	-	-	-	18.98	75.32	87.46	100.00	-
P2-LDPE	0.16	0.79	1.05	2.20	-	-	-	43.79	66.55	81.22
P6-LDPE	0.72	1.66	1.90	3.17	-	-	-	29.01	32.05	70.97
P10-LDPE	0.90	1.67	2.60	3.95	5.08	-	-	-	33.23	55.27
NP-LDHM	0.21	0.66	1.03	1.59	2.06	-	-	-	-	37.11
P2-LDHM	0.35	0.93	1.82	3.25	-	-	-	25.13	64.93	84.95
P6-LDHM	0.19	1.17	2.72	4.74	-	-	-	-	39.14	64.66
P10-LDHM	0.44	1.72	3.07	5.85	-	-	-	-	27.95	67.70
Control	4.15	29.27	40.16	-	-	-	-	21.79	62.32	100.00
SEm±	0.005	0.01	0.02	0.05	0.03	0.52	8.78	7.78	6.75	7.62
$CD_{0.05}$	0.01	0.02	0.05	0.16	0.11	2.02	NS	23.60	19.80	22.14

Decay loss : It increased with the progress of storage period irrespective of treatments. However, initial decaying of fruits was noticed in both NP- PP and NP-LDPE treatment on 7 days of storage. The same treatment recorded the maximum decay loss of 87.30% and 87.46% respectively on 35 day of storage as compared to other treatments (Table 1). The high decay loss in non-perforated packages might be due to condensation of water inside the package which influenced microbial growth causing decay. It might also be due to low O_2 level resulting in anaerobic respiration and finally did lead to the development of off-flavors and off-odors. The minimum decay loss (27.73% and 37.11 %) was observed in fruits packed in P2- PP followed by NP-LDHM, respectively up to77 days of storage. The reduced decay loss might be attributed to limited permeability of gases (CO_2 and O_2) and water vapor which could interplay with physiological processes of fruit. These results were in accordance with the findings of Jena *et al.* (2019).

Fruit color characteristics : Peel color in terms of L, a, b and ΔE increased with the advancement of storage period irrespective of treatments. The color values viz., L, a, b and ΔE in fruit peel was found to be higher at the later stage of storage period. The data presented in Table 2 indicated that the decrease in negative 'a' value during storage ultimately caused decrease in green color of fruits. Increase in 'L' value and 'b' value with the advancement of storage was noticed which is obvious due to increased in 'a' value. This might be due to the degradation of pigments. The present findings were in conformity with the findings of Mukhim *et al.* (2015) in lemon. The slow color development was found in NP-LDHM treatments that might be attributed to opaque nature of the film and prevented light penetration and ultimately reduced the degradation of chlorophyll in fruits during storage.

Fruit firmness : In the present investigation, the fruit firmness was found to increase with the advancement of storage days irrespective of treatments. However, the maximum firmness (47.14 kg) was recorded in P10-PP up to 77 days of storage period, while the minimum firmness (33.29 kg) was recorded in NP-LDHM (Table 3). This might be due to the loss of water resulting in hardening and shrinkage of fruit. In the contrary, fruit firmness showed a decreasing trend with the advancement of storage period in pear fruits as reported by Nath *et al.* (2012).

Juice content : Juice content decreased in all the treatments during storage. The maximum retention of juice percentage was recorded in NP-LDHM followed by non-perforated PP treatments, while the lowest was observed in P10-LDPE packed fruits (Table 3). Better retention of juice content could be attributed to less water loss due to evaporation and transpiration.

Table 2. Effect of packaging materials on peel color changes (L), (a), (b) and color difference (ΔE) of *Assam* lemon during storage. Initial values: L=36.05, a=-6.56, b= 11.35, ΔE= 0.87, DAS= Days after storage and NS= Non-significant.

Treatments	L					a				
	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS
NP-PP	42.53	-	-	-	-	-7.50	-	-	-	-
P2-PP	35.53	46.60	62.69	63.07	60.84	-6.50	-5.58	0.83	3.16	5.15
P6-PP	36.30	40.37	61.54	63.61	-	-7.21	-7.71	-3.07	2.61	-
P10-PP	34.22	47.11	63.29	63.22	62.53	-6.55	-8.15	0.49	3.28	5.09
NP-LDPE	41.16	44.80	-	-	-	-7.98	-5.69	-	-	-
P2-LDPE	33.44	43.23	63.30	-	-	-6.08	-6.85	3.15	-	-
P6-LDPE	39.92	47.08	63.22	66.44	-	-7.41	-8.20	0.28	3.33	-
P10-LDPE	42.99	45.73	60.74	60.80	62.31	-8.02	-6.59	-2.31	3.80	5.60
NP-LDHM	42.34	43.02	46.83	50.94	59.36	-7.95	-7.36	-6.18	-6.19	6.26
P2-LDHM	43.85	45.06	62.50	63.35	-	-8.29	-8.53	-1.60	3.92	-
P6-LDHM	42.80	67.97	53.28	62.27	-	-7.87	-1.13	-6.90	4.06	-
P10-LDHM	37.02	58.58	58.08	61.37	-	-6.97	-5.73	-5.62	4.04	-
Control	37.26	54.66	57.97	-	-	-6.86	-4.35	-3.74	-	-
SEm±	1.3	2.85	3.20	2.19	0.79	0.29	0.95	2.03	1.00	0.91
$CD_{0.05}$	3.65	8.32	9.38	6.52	2.57	0.85	2.76	5.95	2.98	NS

Table 2. Continued.

Treatments	b					ΔE				
	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS
NP-PP	17.45	-	-	-	-	8.95	-	-	-	-
P2-PP	11.16	18.80	29.89	29.19	28.20	1.33	13.12	33.70	33.82	32.21
P6-PP	13.45	14.59	27.72	29.88	-	2.35	5.52	30.75	34.49	-
P10-PP	11.68	19.55	29.92	30.10	29.19	2.51	13.87	33.81	34.49	33.99
NP-LDPE	15.13	16.83	-	-	-	6.54	10.61	-	-	-
P2-LDPE	10.69	16.32	31.84	-	-	2.79	8.82	35.49	-	-
P6-LDPE	14.11	19.64	28.36	32.74	-	4.82	13.89	32.79	38.48	-
P10-LDPE	17.44	18.37	28.01	28.59	29.38	9.37	12.04	30.10	31.92	34.10
NP-LDHM	16.22	16.17	19.36	21.84	28.94	8.08	8.53	13.74	18.32	32.00
P2-LDHM	17.52	18.17	29.07	30.19	-	10.09	11.48	32.25	34.94	-
P6-LDHM	17.58	29.87	23.94	30.97	-	9.29	37.34	21.47	34.45	-
P10-LDHM	13.34	26.06	26.21	28.82	-	2.63	26.94	26.67	32.58	-
Control	13.35	25.96	29.29	-	-	2.36	23.86	28.61	-	-
SEm±	0.84	1.77	1.80	1.38	0.60	1.43	3.35	3.71	2.45	0.78
$CD_{0.05}$	2.45	5.17	5.28	4.11	NS	4.16	9.77	10.88	7.29	NS

Moreover, it was also noted that lemon fruits packed in NP-LDHM showed minimum firmness (33.29 kg) with maximum juice content.

Chemical characteristics : Total soluble solid was found to increase with the advancement of storage period in all the treatments. Fruits packed in P2- PP treatment exhibited rather steadier increase in total soluble solid content as compared to control. The maximum total soluble solid content (7.30°Brix) was recorded in P10-LDPE, while the minimum (6.87°Brix) in P2- PP during storage up to 77 days (Table 4). The steady increase in total soluble solid content could be related to the development of optimum CO_2 and O_2 concentration in the package which slow down their changes. The increase in total soluble solid during storage might also be due to the hydrolysis of polysaccharides and concentration of the juice as a result of dehydration. The result was also in accordance with the findings of Deka *et al.* (2006) in Khasi mandarin.

Fruit acidity was found to increase with the advancement of storage time in all the treatments except NP-PP, NP-LDPE and NP-LDHM. The maximum fruit acidity (6.31%) was recorded in P2- PP whereas,

Table 3. Effect of packaging materials on juice percentage (%) and fruit firmness (kg) of *Assam* lemon during storage. Initial values: Juice=45.50%, Fruit firmness=10.58 kg, DAS= Days after storage and NS= Non-significant.

Treatments	Juice %					Fruit firmness (kg)				
	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS
NP-PP	45.07	-	-	-	-	28.66	-	-	-	-
P2-PP	44.34	40.61	37.78	32.15	28.90	13.00	11.21	14.67	11.53	33.89
P6-PP	42.65	39.28	34.58	29.99	-	15.27	10.59	10.76	17.73	-
P10-PP	40.75	38.68	33.99	22.95	24.91	16.48	15.80	25.29	17.77	47.14
NP-LDPE	44.77	40.14	-	-	-	13.57	43.81	-	-	-
P2-LDPE	44.21	39.12	36.20	-	-	14.31	14.31	22.58	-	-
P6-LDPE	43.37	37.86	33.21	26.93	-	13.16	11.49	15.56	16.81	-
P10-LDPE	40.14	36.92	31.00	25.46	17.44	14.78	20.05	25.32	33.29	41.73
NP-LDHM	45.03	41.99	37.06	34.55	29.09	10.35	10.14	28.69	28.84	33.29
P2-LDHM	44.03	38.49	24.07	30.05	-	11.91	11.97	15.24	41.25	-
P6-LDHM	42.91	36.94	32.65	29.93	-	12.62	8.36	13.63	12.55	-
P10-LDHM	40.57	37.88	30.18	27.00	-	11.66	12.48	19.14	49.83	-
Control	39.78	28.81	18.64	-	-	14.19	47.60	36.33	-	-
SEm±	3.42	1.42	2.36	2.10	2.12	0.36	0.18	0.18	0.08	0.03
$CD_{0.05}$	NS	4.15	6.92	6.23	6.91	1.05	0.51	0.54	0.23	0.10

the minimum (4.25%) in NP-LDHM during storage up to 77 days (Table 4). The decrease in acid content in fruits during storage might be due to utilization of organic acids in respiratory process while, the increase in acid content might be due to the slow conversion of sugar into acids or transpiration rate. Similar increase in acidity during storage was also reported in passion fruit (Patel *et al*. 2009).

Ascorbic acid content of the fruits was found to decrease in all the treatments with the advancement of storage period. The higher retention of ascorbic acid content (9.26 mg/100 g) was recorded in P2- PP followed by both P10-PP and P10-LDPE (5.55 mg/100 g) on 77 days of storage. The maximum retention of acidity and ascorbic acid content in P2-PP packed fruits might be due to low O_2 permeability (1,500 cc/m^2/mil/day at 1 atm) of the said packaging materials as compared with other packaging materials (3,000 and 3,500 cc/m^2/mil/day at 1 atm respectively for LDPE 200 gauge and LDHM 100 gauge packaging materials). The lowest retention of ascorbic acid

Table 4. Effect of packaging materials on total soluble solids and titratable acidity of *Assam* lemon during storage. Initial values: Total soluble solids=5.90°Brix, Titratable acidity=4.35% and DAS= Days after storage.

Treatments	Total soluble solids (°Brix)					Titratable acidity (%)				
	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS
NP-PP	6.07	-	-	-	-	2.92	-	-	-	-
P2-PP	5.93	6.10	6.43	6.70	6.87	4.35	5.63	5.78	4.03	6.31
P6-PP	6.20	6.50	6.80	7.10	-	4.65	5.82	5.63	3.58	-
P10-PP	6.47	6.53	6.90	7.00	7.25	4.91	7.04	6.19	3.65	5.44
NP-LDPE	5.97	6.87	-	-	-	3.84	2.75	-	-	-
P2-LDPE	6.10	6.30	6.90	-	-	4.80	5.57	6.34	-	-
P6-LDPE	6.15	6.15	6.25	6.80	-	4.35	4.35	4.74	4.10	-
P10-LDPE	6.10	6.20	6.70	6.80	7.30	4.37	5.31	6.66	4.10	5.61
NP-LDHM	6.37	6.55	6.90	6.90	7.07	4.18	4.37	5.72	4.42	4.25
P2-LDHM	6.00	6.30	6.83	6.97	-	4.31	6.59	6.70	3.41	-
P6-LDHM	6.32	6.67	6.85	6.83	-	4.44	4.84	5.50	4.91	4.57
P10-LDHM	6.07	6.33	6.70	7.03	-	4.74	6.66	6.34	4.54	-
Control	6.80	7.25	8.53	-	-	4.16	4.54	6.59	-	-
SEm±	0.05	0.05	0.03	0.05	0.02	0.09	0.12	0.47	0.03	0.03
$CD_{0.05}$	0.14	0.14	0.09	0.14	0.07	0.27	0.35	1.39	0.10	0.10

Table 5. Effect of packaging materials on ascorbic acid and chlorophyll content of *Assam* lemon during storage. Initial values: Ascorbic acid = 54.63 mg/100g, Chlorophyll = 0.238 mg/g, and DAS= Days after storage.

Treatments	Ascorbic acid (mg/100 g)					Chlorophyll (mg/g)				
	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS	7 DAS	21 DAS	35 DAS	56 DAS	77 DAS
NP-PP	33.33	-	-	-	-	0.216	-	-	-	-
P2-PP	35.18	25.00	17.59	11.11	9.26	0.211	0.187	0.178	0.102	0.085
P6-PP	42.58	34.26	29.62	16.66	-	0.213	0.173	0.168	0.093	-
P10-PP	41.66	19.44	16.66	11.11	5.55	0.198	0.172	0.161	0.093	0.072
NP-LDPE	34.25	19.44	-	-	-	0.201	0.182	-	-	-
P2-LDPE	34.25	17.59	12.03	-	-	0.194	0.180	0.101	-	-
P6-LDPE	49.07	48.14	30.55	11.11	-	0.194	0.172	0.123	0.082	-
P10-LDPE	22.22	16.66	10.18	8.33	5.55	0.192	0.170	0.116	0.087	0.071
NP-LDHM	38.89	32.41	19.44	12.03	4.63	0.218	0.197	0.180	0.120	0.094
P2-LDHM	34.25	31.48	30.55	11.11	-	0.196	0.194	0.171	0.075	-
P6-LDHM	42.59	27.78	19.44	5.55	-	0.195	0.177	0.168	0.101	-
P10-LDHM	26.85	25.00	24.99	4.63	-	0.192	0.173	0.163	0.072	-
Control	45.37	44.44	27.78	-	-	0.187	0.159	0.099	-	-
SEm±	4.64	3.75	6.18	1.48	1.31	0.002	0.004	0.001	0.002	0.001
$CD_{0.05}$	13.50	10.95	18.13	4.40	4.27	0.007	0.013	0.003	0.005	0.004

content (4.63 mg/100 g) was recorded in NP-LDHM (Table 5). This might be attributed to the process of enzymatic oxidation of L-ascorbic acid to dehydro ascorbic acid. The result was in accordance with the findings of Nath *et al*. (2012) in pear fruits.

In the present investigation, the total chlorophyll content of the peel decreased with the advancement of storage period irrespective of treatments. This might be due to the increase in enzymatic activities like amylase, decarboxylase, chlorophylase and other physiological processes. However, the maximum retention of chlorophyll was observed in NP-LDHM treatment followed by P2- PP (Table 5). Higher retention of chlorophyll content in LDHM treated fruits might be attributed to opaque nature of the said film which might had prevented light penetration resulting in less degradation of chlorophyll and slowed down the changes in peel color.

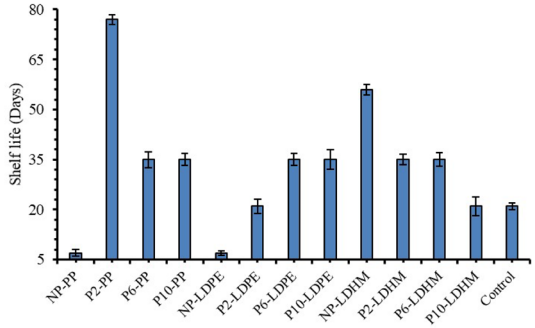

Fig. 1. Shelf life of *Assam* lemon fruits under different packaging materials.

Shelf life : Shelf life plays an important role while determining the freshness of any horticultural commodity as it is directly related to the marketability of the produces. In the present investigation, the fruits showed a longer shelf life when they were packed in different packaging materials as compared to control. The maximum shelf life (77 ±1.41 days) was observed in P_2- PP followed by 56 ±1.58 days in NP-LDHM during storage. However, the minimum shelf life (7 ±1.00 days and 7 ±0.71 days) was recorded in both NP-PP and NP-LDPE treated fruits during storage (Fig. 1). The extended shelf life with different packaging materials might be attributed to the modified environment created by accumulation of CO_2 and depletion of O_2 and maintenance of high humidity inside the packaging material. This helped to maintain turgidity, higher firmness and freshness during storage. The results were in conformity with findings in pear (Kaur *et al.* 2013).

CONCLUSION

The use of plastic films for packaging of *Assam* lemon fruits can be concluded as a cost effective method

for extending the shelf life of the fruits. The study showed that packaging material reduced moisture loss which in turn reduced the PLW of the fruits. Besides the fruits had better green color retention as well extended shelf life upto 77 ±1.41 days as compared to control (21 ±1.00 days). Packaging of the fruits in perforated 2 pin hole PP proved to be the best method for maintain the fruit quality as well as nutritional value throughout the storage period.

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