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Effect of packaging materials and storage conditions on shelf-life of fenugreek leafy vegetable

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Abstract
The present investigation was undertaken in the Department of Processing and Food Engineering, College of Agricultural Engineering, Raichur during 2018-19 to study the effect of packaging materials and storage conditions on shelf-life of fenugreek leafy vegetable. The treatment combination comprised of three storage conditions such as ambient storage (AS), zero energy cool chamber (ZECC) and cold storage (CS) and three different packaging materials such as polyethylene terephthalate (PET), polypropylene (PP) and low density polyethylene (LDPE) with three replication. The freshly harvested fenugreek samples were packaged in three different packaging materials (without vents) and stored in three different conditions. The observations on quality attributes and microbial count were recorded at regular interval up to the end of storage period. It was noticed that the quality parameters were well maintained in cold storage and zero energy cool chamber. It was found, that the least changes in the colour value (*L**, *a** and *b**) was noticed in S_3P_3 (47.72, -12.68 and 17.93) at the end of storage life. There was maximum physiological loss in weight (4.04%) for S_2P_3 on 10th day in ZECC and in CS (4.23%) on 16th day of storage period. The minimum decay (16.47%) was recorded for S_3P_3 on 16th day of storage period. Better retention of total chlorophyll content (from 286.47 to 194.85 mg/100 g) and ascorbic acid (from 88.52 to 52.89 mg/100 g) was recorded for the treatment S_3P_3 on 16th day of storage. microbial populations in ZECC (S_2) storage condition also increased from initial to 37.67, 39.67, 39.33 and 39.12 after 2, 6, 8 and 10 days of storage, respectively and found within the permissible (5×10^6) the same results were obtained for CS (S_3) with an increased value from initial value 28.33, 36.33, 34.33 and 31.67 after 2, 12, 14 and 16 days of storage, respectively.

Keywords: Packaging materials, storage conditions, shelf-life, fenugreek leafy vegetable

Introduction
Vegetables play an important role in meeting the needs of human beings for vitamins and minerals. Amongst all vegetables, the leafy vegetables have a very high protective food value. They are rich in minerals and hence they are called as "Mines of Minerals". Leafy vegetables are rich source of vitamins, minerals and dietary fiber. Being an inexpensive source, these leaves can be used by a large population to meet their dietary requirements. However, leaves are prone to mechanical injury during handling and they lose water because of a high surface area to volume ratio, which make them highly perishable (Kakade *et al.*, 2015) [4]. Leafy vegetables are plant species of which the leafy parts, which may include young, succulent stems, flowers and very young fruits, are used as vegetable (Vorster *et al.*, 2005) [19]. The most widespread and debilitating nutritional disorders, including birth defects, mental and physical retardation, weakened immune systems, blindness and even death has resulted from the habit of non-consumption of fruits and vegetables (Mwangi and Mumbi, 2006) [6].
At present the diet of an average Indian is unbalanced as it consists of mainly cereals only. On an average a normal Indian consumes 375 g of cereals, and 30 g of vegetables daily, against 328 g of cereals, and 316 g of vegetables as per the standard dietary recommendation. Out of total 316 g of vegetables the daily recommendation is 200 g for leafy vegetables (Anon., 2018) [1]. In developing countries, nearly 16 million people die every year from preventable causes and 60% of these from hunger and malnutrition. Most of poor people battle hunger and malnourishment, especially vitamin and mineral deficiencies, which result in stunted growth, weakness and heightened susceptibility to illness (Anon., 2010) [2].
The fenugreek contains abundant amount of bioactive compounds which includes ascorbic acid, carotenoids, chlorophyll, polyphenols and other phytochemicals which provides antioxidant properties apart from health benefits. Ascorbic acid found in fenugreek leafy

vegetables is an effective antioxidant which protect against free radical species and also serves as an enzyme co-factor in many metabolic reactions in the human body. The flavonoids and carotenoids present in fenugreek are good for the retina and lens of the eye which prevent macular degeneration disease by quenching singlet oxygen and scavenging free radical (Simopoulos and Gopalan, 2003) [16] hence there is a necessity to recommend a suitable packaging material and storage condition for enhancing the shelf- life and to maintain nutritional qualities of fenugreek leafy vegetables. In this regard the present research work was carried out to study the effect of packaging materials and storage conditions on shelf-life of fenugreek.

Materials and Methods

Fresh fenugreek *(Trigonella foenum-graecu* L.) bunches were procured after harvesting in the morning hours from Merched village located near the Raichur city. Sorting and grading were done manually to remove diseased and non-uniform fenugreek vegetables. Uniformly sized matured and cleaned fenugreek (Var. local Joara) was used for the investigation. Different packaging materials such as low density polyethylene (LDPE), polypropylene (PP) and polyethylene terephthalate (PET) were procured from M/s. Ashoka Plastics, Hyderabad. Low density polyethylene (LDPE), polypropylene (PP) and polyethylene terephthalate (PET) packaging pouches of 26×20.5 cm dimensions (Locally/ available size) without vents were used for packaging of vegetables. In each packaging pouch a folded tissue paper was placed at the bottom to absorb condensed water in order to avoid rotting. The pre-treated and packaged leafy vegetables were stored under different storage conditions *viz.*, ambient storage (28-40 °C, 55-65%) (AS), zero energy cool chamber (15 to 18 °C, 85-90%) (ZECC) and walk in cold storage (15 °C, 90- 95%) (CS).

Procedure adopted for the experiment

Leafy vegetables (Fenugreek and Coriander) were harvested at mature. The damaged and yellow leaves were removed then the cutting of root (2 cm) from the base of root tip is done. Leafy vegetables were washed in cold water (4-6 °C) with chlorine (120 mg/L) for 2 minutes and rinsed with running tap water. The leafy vegetables dipped in citric acid (0.5%) and ascorbic acid (0.5%) solutions for 2 minutes and surface dried for 15 minutes. It is packaged in different packaging materials and stored in different storage conditions.

Physico-chemical analysis of minimally processed fenugreek leafy vegetable

The colour value of fenugreek was measured as per the procedure of Gulia *et al.,* 2009 [3] using hunters' lab colourimeter. The physiological loss in weight and decay per cent was measured by using the formula given by Tsegay *et al.* (2014) [18]. The total chlorophyll content of fenugreek was determined and quantified using the procedure proposed by Nagata and Yamashita (1992) [7]. The ascorbic acid was analyzed using 2, 6-dichlorophenol indophenol dye titrimetrically as per the method suggested by Sadasivam and Manickam (1992) [13].

Total microbial count (cfu/ml)

Total plate count was determined on nutrient agar pour plates and enumerated after an incubation period. The colonies were counted after the incubation period and the number of cfu/mL of sample were calculated by applying the formula given by Nirmala (2016) [10].

Statistical analysis

Three factorial Completely Randomized Design (FCRD) was used to analyze the data. The experimental design was done with the aid of Design- expert software version 7.0 (Statease Inc., Minneapolis, USA) to study according to general factorial design.

Results and Discussion

Effect of different packaging materials and storage conditions on physico-chemical composition of fenugreek leafy vegetable

Colour values

a) *L** value

The data presented in Table 2 clearly indicated that, It was observed that, the *L** value was decreased with the increase in storage period for all the treatments. The least change in *L** value (from 49.31 to 47.72) was recorded for the treatment S_3P_3 on 16th day of storage, whereas the maximum change in *L** value (from 48.91 to 20.13) was recorded for S_1 P_1. There was a significant difference in the *L** values among all the treatments and found superior over the ambient condition (S_1). Fenugreek, stored under ambient condition (S_1) using different packaging materials *viz.*, No packaging, PET, PP and LDPE, the *L** value was decreased for all the treatments and shelf-life was observed to be only 2 days. The No packaging sample registered less change in *L** value (from 49.03 to 47.30) and found superior compared to samples packaged in PET, PP and LDPE. In the same way, *L** value in ZECC (S_2) storage condition also deceased among all the treatments. The least change in the *L** value was obtained in the sample packaged with LDPE (from 49.03 to 46.67) on 10th day of storage. The same results were observed for CS (S_3) with a decreased *L** value among all the treatments. The least change in *L** value was obtained in the sample stored using LDPE (from 49.03 to 47.72) on 16th day of storage.

The results are in good agreement with the results of Kumar *et al.* (2013). The change in the value of *L** for packaged fenugreek under different storage conditions might be due to bio-chemical reactions, chlorophyll loss and water loss occurred during storage. It could be seen that the rate of change in *L** value was minimum for fenugreek stored in cold storage with different packaging materials. This might be due to better storage condition (temperature and relative humidity) and barrier properties of packaging materials.

b) *a** value

The effect of packaging materials and storage conditions on *a** value of packaged fenugreek leafy vegetable was analyzed and the data are presented in Table 2. It was observed that, the *a** value was increased with the increase in storage period for all the treatments. The least change in *a** value (from -21.12 to -12.68) was recorded for the treatment S_3P_3 on 16th day of storage, whereas the maximum change in *L** value (from -21.12 to -2.06) was recorded for S_1 P_1. There was a significant difference in the *a** values among all the treatments and found superior over the ambient condition (S_1).

For fenugreek, stored under ambient storage (S_1) using different packaging materials *viz.*, No packaging, PET, PP and LDPE, the *a** value was increased for all the treatments and

shelf- life observed to be only 2 days. The No packaging sample registered less change in *a** value (from -21.12 to -20.23) and found superior compared to samples packaged in PET, PP and LDPE. In the same way, *a** value in ZECC (S_2) storage condition also increased among all the treatments. The least change in the *a** value was obtained in the sample packaged with LDPE (from -21.12 to -12.99) on 10th day of storage. The same results were obtained for CS (S_3) with increased *a** value among all the treatments. The least change in *a** value was obtained in the sample stored using LDPE (from -21.12 to -12.68) on 16th day of storage.

The results are in good agreement with the results of Kumar *et al.* (2013) who conducted experiment on effect of different packaging and storage conditions on shelf- life of drumstick leaves. It was clear that *a** values for fenugreek increased during storage period irrespective of storage condition and packaging material. This might be due to high degradation of chlorophyll content and senescence of the fenugreek.

c) *b value**

Fenugreek, stored under ambient condition (S_1) using different packaging materials *viz*., No packaging, PET, PP and LDPE, the *b** value was increased for all the treatments and shelf- life observed to be only 2 days. The data presented in Table 2 indicated that, the No packaging sample registered less change in *b** value (from14.15 to 16.91) and found superior compared to samples packaged in PET, PP and LDPE. In the same way, *b** value in ZECC (S_2) storage condition also increased among all the treatments. The least change in the *b** value was obtained in the sample packaged with LDPE (from 14.15 to 17.95) on 10th day of storage. The same results were obtained for CS (S_3) with an increased *a** value among all the treatments. The least change in *b** value was obtained in the sample stored using LDPE (from 14.15 to 17.93) on 16th day of storage.

The results are in good agreement with the results of Srividya and Ghoora, (2016) [17] who conducted experiment on the postharvest quality and shelf-life of fresh cut fenugreek leaves and impact of aloe vera get coating. The results of *b** values of fenugreek packaged in LDPE increased from 22.3 to 40.6 during the storage periods. The change in the values *b** for packaged fenugreek under different storage conditions might be due to senescence process which causes degradation of the dominant chlorophyll pigment that will unmask the carotenoid.

Physiological loss in weight (%)

The effect of packaging materials and storage conditions on physiological loss in weight of packaged fenugreek was analyzed and the data are presented in Table 4. It was observed that, the physiological loss in weight was increased with the increase in storage period. The highest physiological loss in weight (83.46%) was recorded for the treatment (S_1P_0) on 16th day of storage, whereas the minimum physiological loss in weight (3.87%) was recorded for S_3P_1. There was a non-significant difference in the physiological loss in weight per cent among all the treatments of PET, PP and LDPE for all the storage conditions.

Fenugreek, stored under ambient condition (S_1) using different packaging materials *viz*., No packaging, PET, PP and LDPE. The physiological loss in weight per cent was increased from initial value of 0 to 58.50, 0 to 0.97, 0 to 1.33 and 0 to 2.33% after 2 days of storage period, respectively. In the same way, physiological loss in weight per cent a in ZECC (S_2) storage condition also increased for all the treatment and there was maximum physiological loss in weight (4.04%) for S_2P_3 on 10th day of storage period. The same results were obtained for CS (S_3) and the maximum physiological loss in weight was found for S_3P_3 (4.23) on 16th day of storage.

Similar results were obtained by Narang *et al.* (2016) [8] for packaging of fresh fenugreek under refrigerated condition. Results found that the weight loss of fenugreek packaged in different packaging materials was ranged from 0.25 to 50% at the end of 49 days of storage period. The loss of water is a natural process and is attributed to the respiration and other senescence-related metabolic processes during storage. The weight loss of leafy vegetables depends upon the water vapour transmission rate (WVTR) of packaging film. The WVTR of PET film was less hence less water lost from the fenugreek packaged in PET film in all storage conditions (S_1 S_2 and S_3). The physiological loss in weight of fenugreek packaged with LDPE was less as compared to S_1P_0, S_2P_0 and S_3P_0.

Decay percent (%)

The effect of packaging materials and storage conditions on decay per cent of packaged fenugreek was analyzed and the data are presented in Table 4. It was observed that, the decay per cent was increased with the increase in storage period. The highest decay of **(**100%) was recorded for all the treatment of S_1P_0 on 16th day of storage, whereas the minimum decay (16.47%) was recorded for S_3 P_3. There was a significant difference in the decay percentage among all the treatments and found superior over the ambient condition (S_1). For fenugreek, stored under ambient condition (S_1) using different packaging materials *viz*., No packaging, PET, PP and LDPE, the physiological loss in weight was increased with increase in storage period for all the treatment of S_1. In the same way, decay percentage in ZECC (S_2) storage condition also increased for all the treatment and there was minimum decay (15.67%) for S_2P_1 on 10th day of storage period. The same results were obtained for CS (S_3) with a increased value from initial value 0 to 100% and the minimum weight loss was found for S_3P_3 (16.47) on 16th day of storage.

It observed that the decay per cent (%) will increased during storage period irrespective of packaging and storage conditions but more in case of ambient conditions. This might be due to properties of packaging material, storage conditions, microbial count and condensation of moisture on leaves. The similar results are good agreement with Sharangi *et al.* (2015) [14] who experimented on decay per cent of coriander under different packaging materials. In this research decay per cent was reported as 23 and 39% for poly packet and control condition under refrigerated condition and 35.67 and 51%, respectively for room temperature on 12th day of storage.

Total chlorophyll content

The effect of packaging materials and storage conditions on chlorophyll content of packaged fenugreek was analyzed and the data are presented in Table 6. Fenugreek, stored under ambient condition (S_1) using different packaging materials *viz*., No packaging, PET, PP and LDPE, the chlorophyll content was decreased for all the treatments and shelf- life observed to be only 2 days. The no packaging sample registered better retention of chlorophyll content (from 286.47

to 250.76 mg/100 g) and found superior compared to samples packaged in PET, PP and LDPE. But, the chlorophyll content of fenugreek in ZECC (S_2) storage condition increased initially (2nd day) for PET, PP and LDPE then decreased. The better retention in the chlorophyll content was obtained in the sample packaged with LDPE (from 286.47 to 191.94 mg/100 g) on 10th day of storage. Correspondingly, the same results were obtained for CS (S_3). The chlorophyll content of fenugreek was initially increased (2th day) for PET, PP and LDPE then decreased. The better retention in the chlorophyll content was observed in samples packaged with LDPE (from 286.47 to 19.85 mg/100 g) on 16th day of storage period.

The chlorophyll content was decreased with the increase in storage period for all the treatments. This might be due to chlorophyll content of leafy vegetables is largely dependent on the dynamics of gaseous atmosphere within packaging materials. Low oxygen content retards the degradation rate of chlorophyll and also because of senescence and transpiration from the exposed surface area of the leaves. A slight rise in chlorophyll was observed on 2nd day of storage for S_2P_1, S_2P_2, S_2P_3, S_3P_1, S_3P_2 and S_3P_3 treatments because of oxygen content in packaging materials but later on the packaged environment become anaerobic and the chlorophyll content decreased. The actual reason for chlorophyll reduction using different packaging material and storage condition were not available but the results are in good agreement with the results of Shen *et al.* (1999) [15] who experimented on the effects of modified atmosphere packaging and blanching on quality of Bok Choy during storage. In this research degradation of chlorophyll in Bok Choy was 32% during 10 days of storage at 10 °C.

Ascorbic acid

The effect of packaging materials and storage conditions on ascorbic acid of packaged fenugreek was analyzed and the data are presented in Table 7. It was observed that, the ascorbic acid values were decreased with the increase in storage period for all the treatments. The initial ascorbic acid of fresh fenugreek was 88.52 mg/100 g. The maximum retention of ascorbic acid (88.52 to 52.89 mg/100 g) was recorded for the treatment S_3P_3 on 16th day of storage. Fenugreek, stored under ambient condition (S_1) using different packaging materials *viz.*, No packaging, PET, PP and LDPE, the ascorbic acid content was decreased from initial value of 88.52 to 29.24, 39.02, 39.32 and 41.78 mg/100 g after 2 days of storage period, respectively. In the same way, ascorbic acid in ZECC (S_2) storage condition also decreased for all the treatments and there was maximum retention for S_2P_3 on 10th day of storage. The same results were obtained for CS (S_3) with a decreased value from initial value 88.52 to 18.59 mg/100 g. and the maximum ascorbic acid retention was found for S_3P_3 (52.89 mg/100 g) on 16th day of storage.

The ascorbic acid content was decreased with the increase in storage period for all the treatments. This might be due to oxidation of ascorbic acid to dehydroascorbic acid. Similar results were recorded by Negi and Roy (2004) [9] who conducted experimented on the changes in ascorbic acid of amaranths during storage periods. The result found that 65% ascorbic acid was lost on the 6th day of storage in polyethylene bags.

Microbial population

The effect of packaging materials and storage conditions on microbial population of packaged fenugreek was analyzed and the data are presented in Table 8. It was observed that, the microbial populations were increased with the increase in storage period for all the treatments. Initial microbial population of fresh fenugreek was 4.08×10^6. There was a significant difference in the microbial population among all the treatments and found superior over ambient condition (S_1). For fenugreek, stored under ambient condition (S_1) using different packaging materials *viz.*, No packaging, PET, PP and LDPE, the microbial populations were increased from initial value to 41.00, 50.00, 49.00, 48.00 cfu$\times 10^6$ ml on 2nd days of storage period, respectively. In the same way, microbial populations in ZECC (S_2) storage condition also increased from initial to 37.67, 39.67, 39.33 and 39.12 after 2, 6, 8 and 10 days of storage, respectively and found within the permissible (5×10^6) the same results were obtained for CS (S_3) with an increased value from initial value 28.33, 36.33, 34.33 and 31.67 after 2, 12, 14 and 16 days of storage, respectively.

It was observed that the microbial population increased during storage period irrespective of packaging and storage conditions. This might be due to properties of packaging materials, storage conditions, storage days and also the availability of moisture and nutrients which have tremendous impact on the growth of microbial population. The samples packaged in LDPE showed less growth of microorganism and the count was within the permissible limit up to 16th day. This might be due to lower temperature and low metabolic activity. The results are good agreement with Pirovani *et al.* (1998) [12] and Piagentini and Guemen, (2002) [11] who experimented on influence of packaging and chemical treatment on minimally processed spinach and lettuce, respectively.

Shelf-life

From the data represented in all the tables, it is clearly seen that, fenugreek leafy vegetable could be stored up to 2 days in ambient storage (AS) in all packaging materials. Fenugreek packaged using different packaging materials *viz.*, No packaging, PET, PP and LDPE in ZECC condition could be stored for duration of 2, 6, 8 and 10 days, respectively with better quality attributes and within safe limit of microbial load. It was concluded that fenugreek packaged using different packaging materials *viz.*, No packaging, PET, PP and LDPE in CS condition could be stored for duration of 2, 12, 14 and 16 days, respectively with better quality attributes and within safe limit microbial load.

Table 1: Effect of storage conditions and packaging materials on color value *L** of fenugreek leafy vegetable

Storage conditions	Packaging materials	*L** value									
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	49.03	47.30	-	-	-	-	-	-	-	-
	PET (P1)	49.03	33.27	-	-	-	-	-	-	-	-
	PP (P2)	49.03	35.47	-	-	-	-	-	-	-	-
	LDPE (P3)	49.03	37.31	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging(P0)	49.03	47.45	-	-	-	-	-	-	-	-
	PET (P1)	49.03	48.35	47.61	46.79	-	-	-	-	-	-
	PP (P2)	49.03	48.48	48.28	47.46	46.74	-	-	-	-	-
	LDPE (P3)	49.03	48.61	48.35	48.14	46.98	46.67	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	49.03	47.27	-	-	-	-	-	-	-	-
	PET (P1)	49.03	48.90	48.45	48.04	47.6	47.07	-	-	-	-
	PP (P2)	49.03	49.18	48.75	48.49	48.33	47.93	47.76	-	-	-
	LDPE (P3)	49.03	49.27	49.14	48.56	48.46	48.01	48.00	47.89	47.72	-
	Mean	49.03	45.07	44.57	43.53	42.83	42.25	41.21	39.58	38.00	36.00
	SEm±	0.16	0.15	0.11	0.12	0.15	0.17	0.18	0.24	0.17	0.25
	CV	1.94	2.03	1.43	1.7	2.1	2.43	2.61	3.6	3.81	4.15
	CD @ 1%	1.60	1.55	1.07	1.25	1.54	1.73	1.82	2.41	1.73	2.52

'-'Indicates termination of treatment

Table 2: Effect of storage conditions and packaging materials on color value *a** of fenugreek leafy vegetable

Storage conditions	Packaging materials	*a** value									
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	-21.13	-20.23	-	-	-	-	-	-	-	-
	PET (P1)	-21.56	-4.78	-	-	-	-	-	-	-	-
	PP (P2)	-21.03	-4.54	-	-	-	-	-	-	-	-
	LDPE (P3)	-21.38	-5.8	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	-21.17	-20.12	-	-	-	-	-	-	-	-
	PET (P1)	-20.63	-20.11	-18.22	-12.14	-	-	-	-	-	-
	PP (P2)	-21.44	-20.07	-18.42	-17.38	-12.18	-	-	-	-	-
	LDPE (P3)	-20.21	-20.11	-19.18	-18.64	-16.34	-12.99	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	-21.23	-20.22	-	-	-	-	-	-	-	-
	PET (P1)	-21.16	-20.46	-19.73	-18.58	-17.49	-15.61	-12.21	-	-	-
	PP (P2)	-21.42	-20.53	-20.27	-19.28	-17.92	-15.94	-14.24	-12.23	-	-
	LDPE (P3)	-20.87	-20.38	-20.45	-20.28	-18.47	-18.16	-16.87	-14.04	-12.68	-
	Mean	-21.12	-16.10	-14.96	-13.49	-11.43	-10.01	-8.25	-7.49	-6.83	-5.69
	SEm±	0.099	0.057	0.042	0.056	0.064	0.075	0.068	0.1	0.047	0.027
	CV	2.81	2.09	1.62	2.38	3.14	4.26	4.57	7.57	3.83	2.564
	CD @ 1%	0.99	0.58	0.42	0.55	0.65	0.75	0.69	1.02	0.47	0.26

'-'Indicates termination of treatment

Table 3: Effect of storage conditions and packaging materials on color value b* of fenugreek leafy vegetable

Storage conditions	Packaging Materials	*b** value									
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	14.21	16.91	-	-	-	-	-	-	-	-
	PET (P1)	14.16	21.29	-	-	-	-	-	-	-	-
	PP (P2)	14.12	20.79	-	-	-	-	-	-	-	-
	LDPE (P3)	14.22	16.93	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	14.15	15.21	-	-	-	-	-	-	-	-
	PET (P1)	14.09	14.22	14.56	18.19	-	-	-	-	-	-
	PP (P2)	14.08	14.73	16.12	17.83	18.09	-	-	-	-	-
	LDPE (P3)	14.22	14.41	16.09	17.20	17.52	17.95	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	14.20	15.75	-	-	-	-	-	--	-	-
	PET (P1)	14.09	14.66	15.56	16.05	16.51	16.94	18.23	-	-	-
	PP (P2)	14.18	14.46	14.58	15.07	15.39	16.09	17.36	18.00	-	-
	LDPE (P3)	14.13	14.38	14.48	14.83	14.98	15.49	16.64	17.11	17.93	-
	Mean	14.15	16.15	17.22	18.28	18.84	19.66	21.17	21.88	22.54	23.51
	SEm±	0.36	0.11	0.074	0.076	0.076	0.078	0.1	0.093	0.1	0.064
	CV	4.11	4.12	2.59	2.5	2.42	2.38	2.901	2.53	2.711	1.631
	CD @ 1%	0.28	1.11	0.75	0.77	0.77	0.78	1.03	0.92	1.02	0.65

'-'Indicates termination of treatment

Table 4: Effect of storage conditions and packaging materials physiological loss in weight of fenugreek leafy vegetable

Storage conditions	Packaging Materials	Physiological loss in weight (%)									
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	0	58.50	-	-	-	-	-	-	-	-
	PET (P1)	0	0.97	-	-	-	-	-	-	-	-
	PP (P2)	0	1.33	-	-	-	-	-	-	-	-
	LDPE (P3)	0	2.33	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	0	37.60	-	-	-	-	-	-	-	-
	PET (P1)	0	0.21	1.02	2.12	-	-	-	-	-	-
	PP (P2)	0	0.34	1.95	2.74	4.07	-	-	-	-	-
	LDPE (P3)	0	0.67	2.04	3.20	3.78	4.57	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	0	28.83	-	-	-	-	-	-	-	-
	PET (P1)	0	0.05	0.60	0.98	1.17	2.17	3.17	-	-	-
	PP (P2)	0	0.25	0.95	1.03	1.57	2.04	3.60	4.04	-	-
	LDPE (P3)	0	0.65	1.25	1.53	2.12	2.45	3.72	4.05	4.23	-
	Mean	0.00	10.88	14.88	17.05	19.34	21.13	22.61	23.75	24.43	25.04
	SEm±	0	0.12	0.042	0.066	0.076	0.047	0.042	0.049	0.064	0.068
	CV	0	5.37	1.737	2.315	2.367	1.344	1.113	1.23	1.56	1.625
	CD @ 1%	0	1.25	0.42	0.66	0.77	0.47	0.42	0.49	0.65	0.69

'-'Indicates termination of treatment

Table 5: Effect of storage conditions and packaging materials decay per cent of fenugreek leafy vegetable

Storage conditions	Packaging materials		Decay per cent (%)								
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	0	67.67	-	-	-	-	-	-	-	-
	PET	0	64.67	-	-	-	-	-	-	-	-
	PP	0	59.33	-	-	-	-	-	-	-	-
	LDPE	0	52.67	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	0	22.67	-	-	-	-	-	-	-	-
	PET	0	1.42	8.43	17.37	-	-	-	-	-	-
	PP	0	1.25	1.65	7.67	16.67	-	-	-	-	-
	LDPE	0	0.57	1.6	3.33	7	15.67	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	0	10.33	-	-	-	-	-	-	-	-
	PET	0	0	0.54	1.42	5.47	10.39	17.16	-	-	-
	PP	0	0	0	0.61	1.65	5.53	10.05	16.96	-	-
	LDPE	0	0	0	0	0.56	1.49	5.24	9.45	16.47	-
	Mean	0.00	23.38	28.24	33.92	43.55	52.33	58.57	63.18	68.40	74.76
	SEm±	0.0000	0.2900	0.1900	0.1600	0.1600	0.1400	0.1100	0.9900	0.9400	0.7600
	CV	0.0000	7.4900	4.0310	2.8570	2.2100	1.6440	1.1270	9.3900	8.2230	6.0600
	CD @ 1%	0	2.94	1.94	1.63	1.61	1.41	1.11	9.98	9.93	7.59

'-'Indicates termination of treatment

Table 6: Effect of storage conditions and packaging materials on chlorophyll (mg/100 g) of fenugreek leafy vegetable

Storage conditions	Packaging Materials		Chlorophyll (mg/100 g)								
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	286.89	250.76	-	-	-	-	-	-	-	-
	PET (P1)	287.1	70.68	-	-	-	-	-	-	-	-
	PP (P2)	284.15	70.61	-	-	-	-	-	-	-	-
	LDPE (P3)	286.08	73.55	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	287.53	251.34	-	-	-	-	-	-	-	-
	PET (P1)	286.85	289.12	248.46	190.34	-	-	-	-	-	-
	PP (P2)	286.67	294.34	258.46	210.28	191.42	-	-	-	-	-
	LDPE (P3)	287.97	296.61	268.67	225.45	210.92	191.94	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	285.65	251.82	-	-	-	-	-	-	-	-
	PET (P1)	286.34	290.19	257.9	231.76	219.35	213.96	193.87	-	-	-
	PP (P2)	285.83	295.43	268.55	240.63	220.17	218.29	210.42	194.19	-	-
	LDPE (P3)	286.58	298.4	278.24	251.07	228.89	220.12	215.44	209.51	194.85	-
	Mean	286.47	227.74	188.93	141.38	126.73	103.7	83.87	68.41	53.5	40.39
	SEm±	0.23	0.16	0.073	0.036	0.095	0.0362	0.058	0.048	0.044	0.047
	CV	0.472	0.424	0.231	0.152	0.451	0.363	0.413	0.411	0.491	0.696
	CD @ 1%	2.27	1.63	0.73	0.36	0.96	0.62	0.58	0.472	0.44	0.47

'-'Indicates termination of treatment

Table 7: Effect of storage conditions and packaging materials on ascorbic acid (mg/100 g) of fenugreek leafy vegetable

Storage conditions	Packaging Materials	Ascorbic acid (mg/100 g)									
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	92.41	29.24	-	-	-	-	-	-	-	-
	PET (P1)	88.76	39.02	-	-	-	-	-	-	-	-
	PP (P2)	85.18	39.32	-	-	-	-	-	-	-	-
	LDPE (P3)	87.73	41.78	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	87.29	35.03	-	-	-	-	-	-	-	-
	PET (P1)	89.36	70.91	67.78	50.45	-	-	-	-	-	-
	PP (P2)	87.17	82.14	70.58	67.68	50.52	-	-	-	-	-
	LDPE (P3)	90.46	84.04	73.97	71.44	68.79	52.56	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	87.65	38.14	-	-	-	-	-	-	-	-
	PET (P1)	89.14	80.08	70.55	69.45	57.20	51.81	49.50	-	-	-
	PP (P2)	87.87	83.82	75.55	73.20	65.38	60.15	56.74	50.43	-	-
	LDPE (P3)	89.16	80.30	78.30	76.44	74.36	67.84	60.18	59.39	52.89	-
	Mean	88.52	58.65	46.75	40.56	32.48	26.18	20.59	16.21	12.29	8.93
	SEm±	0.25	0.26	0.2	0.15	0.2	0.13	0.091	0.083	0.1	0.08
	CV	1.67	2.621	2.545	2.242	3.71	3.033	2.648	3.075	4.97	5.38
	CD @ 1%	2.49	2.59	2.04	1.53	2.02	1.35	0.92	0.84	1.02	0.80

'-'Indicates termination of treatment

Table 8: Effect of storage conditions and packaging materials microbial population of fenugreek leafy vegetable

Storage conditions	Packaging Materials	Microbial population (cfu× 10^6/ ml)									
		Fresh	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day
S1 (Ambient Storage)	No packaging (P0)	4.08	41.00	-	-	-	-	-	-	-	-
	PET (P1)	4.08	50.00	-	-	-	-	-	-	-	-
	PP (P2)	4.08	49.00	-	-	-	-	-	-	-	-
	LDPE (P3)	4.08	48.00	-	-	-	-	-	-	-	-
S2 (ZECC)	No packaging (P0)	4.08	37.67	-	-	-	-	-	-	-	-
	PET (P1)	4.08	9.33	22.33	39.67	-	-	-	-	-	-
	PP (P2)	4.08	8.00	20.67	27.33	39.33	-	-	-	-	-
	LDPE (P3)	4.08	5.33	18.33	25.33	38.67	39.12	-	-	-	-
S3 (Cold Storage)	No packaging (P0)	4.08	28.33	-	-	-	-	-	-	-	-
	PET (P1)	4.08	8.00	10.33	13.33	19.33	29.33	36.33	-	-	-
	PP (P2)	4.08	6.67	9.33	13.33	18.33	21.33	28.33	34.33	-	-
	LDPE (P3)	4.08	5.67	8.33	11.67	15.67	17.67	20.67	28.67	31.67	-
	Mean	4.08	150.53	174.03	206.11	239.11	274.14	373.67	444.58	530.36	592.75
	SEm±	0.079	0.16	0.17	0.18	0.29	0.24	0.16	0.23	0.17	0.17
	CV	1.54	0.626	0.598	0.524	0.724	0.53	0.252	0.313	0.196	0.173
	CD @ 1%	0.78	1.58	1.69	1.78	2.86	2.42	1.58	2.34	1.69	1.69

'-'Indicates termination of treatment

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