Effects of ultraviolet irradiation, pulsed electric field, hot water dip and ethanol vapours treatment on keeping and sensory quality of mung bean (*Vigna radiata* L. Wilczek) sprouts

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Abstract The objective of this research work was to evaluate the effects of UV- irradiation, pulsed electric field (PEF), hot water dip (HWD) and ethanol vapours on the quality and storage life of mung bean sprouts (*Vigna radiata* L. Wilczek). The sprouts were subjected to various treatments viz., UV-Irradiation (10 kJm^{-2} in laminar flow chamber for 1 h), PEF (10,000 V for 10s), HWD (50 °C for 2 min) and ethanol vapours (1 h); and then stored in thermocol cups wrapped with perforated cling films at room (25 ± 1 °C) and low (7 ± 1 °C) temperature conditions. The sprouts were analyzed regularly at 24 h interval for sprout length, sprout weight, total soluble solids (TSS), titratable acidity, non-enzymatic browning, total plate count and overall acceptability. Sprout length and weight increased during storage. There was no significant effect of various treatments on sprout length and weight, except in ethanol treatment, where suppression was observed. HWD showed higher TSS and acidity than that of control. The least browning was observed in ethanol treatment. The total plate count was not significantly affected by various treatments. Overall acceptability under various treatments decreased during storage period both at room and low temperature. Hot water and ethanol vapour treated sprouts showed higher acceptability than other treatments. However, the acceptability scores for sprouts remained within the acceptable range (≥ 6) up to 72 h at room temperature and 120 h at low temperature conditions.

Keywords Ultraviolet irradiation · Pulsed electric field · Ethanol vapours · Hot water dip · Mung bean sprouts · Sensory properties

Introduction

Mung bean (*Vigna radiata* L. Wilczek) is a leguminous species/pulse crop, grown for its protein rich edible seeds. It is native to India and Pakistan and also cultivated in Iran, Vietnam, China and the Phillipines. India is the leading country in the production of mung bean with around 45 % of the world production. In India, mung bean ranks third among the pulse crop, after chick pea and pigeonpea (Singh and Yadav 1978). With about 67 % carbohydrate, 27 % protein, 1.46 % lipids, 132 mg calcium, 380 mg phosphorus and 2.91 mg niacin (moisture free basis), mung bean is a rich source of nutrients (Poehlman 1991). Protein in mung beans is comparatively rich in lysine, an amino acid deficient in cereal grains. Sprouting is the practice of soaking and leaving seeds until they germinate and begin to sprout. Bean sprouts are highly perishable and thus have an inherently short shelf-life. Sprouts remain in saleable conditions at 0 °C and 95 % to 100 % relative humidity (RH) for 6–7 days while exposure to 20 °C for 30 min each day can reduce the storage-life by half. Symptoms of deterioration include; darkening of the root and cotyledons, development of dark streaks on the hypocotyl, and eventual development of sliminess, decay, and a musty odour (Lipton et al. 1981). This rapid quality loss at relatively modest temperature emphasizes the critical need to enhance the shelf life and maintain the keeping quality during storage.

Kharel and Hasinaga (1996) reported that high electric field exposure for short period suppresses the respiration rate and

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extended the freshness of strawberries. Arvanitoyannis et al. (2009) reviewed that the irradiation treatment was extremely beneficial in terms of prolonging the fruit and vegetable shelf life by 3–5 times. Pre-exposure to short UV radiation slowed down respiration and ripening of fruits stored at room temperature, thus enhancing their shelf life (Baka et al. 1999; Siddiqui et al. 2001). Pao et al. (2008) reported the effectiveness of hot water immersions in eliminating of microorganisms in alfalfa and mung bean sprouts. Ethanol vapour treatment also enhanced the shelf life of guava by delaying ripening and decreasing surface microflora growth (Siddiqui et al. 2005). The ethyl acetate extracts of mung bean sprouts were more effective than from seeds and could be a potential source of antioxidants linked with health benefits (Kim et al. 2012). Day (1990) reported enhanced shelf life of bean sprouts packaged in microperforated films due to reduced respiration rate. It was observed that perforated film packaging helped to maintain the quality of fresh sprouts by reducing water loss (DeEll and Vigneault 2000). In spite of their importance as a fresh or cooked vegetable, and a good source of protein, information on the maintaining the keeping quality of mung bean sprouts is scant. Therefore, the objective of the present study was to evaluate the effects of different treatments on the quality and storage life of mung bean sprouts.

Materials and methods

Plant material

The experimental work was carried out in Centre of Food Science and Technology, CCS Haryana Agricultural University, Hisar, Haryana, India. Mung beans variety Muskan were procured from pulse section, Dept. of Plant Breeding, CCS HAU, Hisar. Mung seeds were cleaned, washed and soaked in 4–5 volumes of water (22–25 °C) for 12 h under ambient laboratory conditions. At the end of the period, the water was drained and the seed samples were allowed to germinate in sprout maker (Novelle Plast, Delhi) for 24 h at 25±1 °C.

Treatments and storage conditions

Sprouted mung beans were divided into 5 lots of equal amount for treatments and then subjected to the various treatments viz. Pulsed Electric Field (PEF) [by PEF generator designed by Ambala Associates, Ambala (Haryana), 50 Hz, 10,000 V pulses for 10 s], Hot water dip (HWD) (50 °C for 2 min), Ethanol vapours (In a glass chamber saturated with ethanol vapours for 1 h), and UV irradiation (10 kJm⁻² in laminar flow chamber for 1 h). Untreated sprouts were used as control.

The sprouts from each treatment were packaged in thermocol cups (~200 ml volume) and wrapped with perforated

cling films. Water soaked filter paper was placed along the inner sides of thermocol cups to maintain high humidity inside. There were ~100 g sprouts per pack and the packs were stored in dark at room (25±1 °C) and low (7±1 °C) temperature conditions maintained in biochemical oxygen demand (B.O.D.) incubator. The sampling for various parameters was done regularly at 24 h interval up to 72 h at room and 120 h at low temperature conditions.

Chemicals

The chemicals used in investigation were analytical grade reagents (A.R.) from standard suppliers like B.D.H., C.D.H., S.D. fine chemicals and Sisco Research lab, India.

Physico-chemical properties of bean sprouts

Sprout length was measured by taking the mean of hypocotyls length of 10 sprouts and expressed in cm. Total soluble solids (TSS) were measured by using hand refractometer (Erma, Japan) of 0–32 % range. Two g sprouts (without seed coat) were squeezed by hand through muslin cloth. The juice extracted was immediately used for determination of TSS and the values were expressed in %. Acidity was estimated as per the method described by AOAC (1995). 2.5 g of sample was macerated with 5 ml of water and allowed to stand for 30 min at room temperature. Total final volume was made up to 10 ml with distilled water and titrated against 0.01 N NaOH using few drops of 1 % phenolphthalein solution. From the volume of alkali used, acidity (%) was calculated in terms of citric acid.

Non-Enzymatic Browning was recorded for fresh product and stored product, by the procedure as described by Ranganna (2003). Two g of sample was macerated in 10 ml of 60 % ethyl alcohol. The resulting solution was kept overnight and filtered through Whatman filter paper no. 1 to obtain a clear solution. The absorbance of solution was measured at 440 nm using 60 % alcohol as blank. The browning was expressed in terms of optical density (O.D.) of the solution.

Microbial analyses

Ten gram sprouts were dipped in 100 ml of distilled water for 1 h and then water samples were diluted by serial dilution technique. One ml aliquot of the appropriate dilution was poured with the help of a sterilized pipette in a sterilized petriplate in triplicate, for two successive dilutions. About 10–15 ml of media (nutrient agar) was then poured, mixed and then allowed to set at room temperature for an hour. The plates in inverted position were incubated in a BOD incubator at 37 °C for 36 h. The colonies were counted in plates containing 30–300 colonies. The results were expressed as log cfu/g.

Overall acceptability

Sensory evaluation of treated sprout and control samples was carried out on 9-point hedonic scale. In order to take care of the variation in individual preferences for various organoleptic characteristics a panel of 10 trained judges from within the Centre of Food Science and Technology of the University was constituted. Sprouted mung beans were presented to the judges to evaluate for appearance, color, texture, and taste. Overall acceptability (OA) of sample was calculated as mean score given to it by a judge for these parameters.

Statistical analysis

Three replicates of each treated samples were used for analysis. The data obtained in the present investigation was subjected to analysis of variance (ANOVA) technique and analyzed according to two factorial completely randomized designs (CRD). The critical difference value at 5 % level was used for making comparison among different treatments during storage.

Results and discussion

Sprout length

Table 1 shows sprout length of mung bean sprouts over a storage period of 48 h and 120 h when stored at room and low temperature, respectively. At room temperature, there was a progressive increase in the sprout length with increasing storage period. Sprout length under various treatments ranged from 0.92–3.28 cm and 0.88–1.60 cm during storage period of 48 h at room temperature and 120 h at low temperature, respectively. There was no significant difference in the sprout length under various treatments, except in

ethanol treatment where reduced growth was observed during storage. Suppression of sprout length was observed due to inhibition of ethylene synthesis after ethanol treatment (Siddiqui et al. 2005).

Total soluble solids (TSS)

Table 2 shows TSS of mung bean sprouts over a storage period of 48 h and 120 h when stored at room and low temperature, respectively. At room temperature, TSS of sprouts first increased (from 13.2 to 15.5 %) up to 24 h and then decreased to 7.2 % at 48 h. There was no significant effect of various treatments on the TSS of sprouts, except in hot water dip (HWD) treatment, where increased TSS was observed. Throughout the storage period, maximum TSS was maintained in HWD treated sprouts. This might be due to more conversion of starch into sugars resulting in higher TSS. The possible reason of decrease in TSS on storage periods could be due to utilization of free sugars for various metabolic activities. Ansari and Feridoon (2007) reported increased %TSS in hot water treated Valencia and local oranges of Siavarz during storage. Ozdemir et al. (2009) also showed that TSS increased after hot water dips of Fuyun persimmons. At low temperature trends were similar as room temperature. TSS of sprouts first increased (from 13.5 to 14.2 %) upto 48 h and then decreased to 10.2 % by 120 h of storage. Total soluble solids (TSS) of the sprouts were not significantly affected by PEF treatment. However, Kuldiloke et al. (2008) observed decreased TSS of sugar cane on exposure to High Electric Field Pulses (HELP). Contradictorily, application of pulsed electric field was found to increase the °brix of juice for both apples and carrots (Praporscic et al. 2007). In the present investigation, no significant effect of ethanol vapour treatment was observed on TSS of sprouts. However, Zavala et al. (2005) reported that ethanol vapour increased the total soluble solids content in strawberries stored at 7 °C. Contradictorily,

Table 1 Effect of different treatments on quality characteristics of mung bean sprouts during storage at room temperature and low temperature (T- Treatments; S- Storage; C.D.- Critical Difference)

Treatments	Period of storage (h)									
	Room temperature (25±1 °C)				Low temperature (7±1 °C)					
	0	24	48	Mean	24	48	72	96	120	Mean
Sprout Length (cm) (<i>n</i> =3)										
Control	1.00	2.28	3.06	2.11	1.22	1.26	1.40	1.50	1.52	1.29
PEF	0.96	2.00	3.22	2.06	1.08	1.22	1.38	1.44	1.48	1.24
HWD	1.04	2.20	3.38	2.20	1.16	1.32	1.50	1.58	1.60	1.35
Ethanol	0.92	1.70	2.58	1.73	0.90	0.98	1.00	1.12	1.14	1.00
UV	0.96	1.88	3.20	2.01	1.14	1.28	1.26	1.38	1.38	1.22
Mean	0.97	2.01	3.08		1.10	1.21	1.30	1.40	1.42	
C.D. at 5 %	T=0.21; S=0.16; T x S=0.36				T=0.10; S=0.12; T x S=0.18					

Table 2 Effect of different treatments on quality characteristics of mung bean sprouts during storage at room temperature and low temperature (T- Treatments; S- Storage; C.D.- Critical Difference)

Treatments	Period of storage (h)									
	Room temperature (25±1 °C)				Low temperature (7±1 °C)					
	0	24	48	Mean	24	48	72	96	120	Mean
Total soluble solids (TSS %) (<i>n</i> =3)										
Control	13.5	14.2	7.2	11.6	14.0	14.2	13.2	11.0	10.2	12.7
PEF	13.2	14.2	7.5	11.6	14.0	13.7	13.2	11.2	10.0	12.5
HWD	14.5	15.5	8.5	12.8	15.2	15.2	14.0	12.5	11.3	13.8
Ethanol	13.2	14.0	7.2	11.5	14.0	14.0	13.5	11.2	9.6	12.6
UV	13.2	14.5	7.7	11.8	14.0	13.7	13.2	11.4	9.8	12.7
Mean	13.5	14.5	7.6		14.2	14.2	13.4	11.4	10.2	
C.D. at 5 %	T=0.3; S=0.2; T x S=N.S.				T=0.2; S=0.3; T x S=N.S.					

Atta-Aly et al. (1998) reported that when mature-green tomato fruits were treated with ethanol vapours, fruits showed a significant reduction in total soluble solids during storage. No significant effect of UV irradiation was observed on TSS of sprouts. Similar non-significant effect on %TSS of egg plants by UV-C treatments has earlier been reported by Karasahin et al. (2005). Patil et al. (2004) observed that total soluble solids (%) were not affected due to irradiation or storage of early season fruit. However, late season fruit had lower soluble solids (%) and acidity values than early season fruit, and the soluble solids:acid ratios after 35 days of storage were slightly higher than the initial ratios.

Acidity

Table 3 shows the acidity of mung bean sprouts under different treatments and storage. There was a progressive decrease in titratable acidity with increasing storage period. The decrease could be due to utilization of acids for respiratory activity or other metabolic processes. There was no

significant effect of PEF and UV treatments on acidity of the sprouts, but hot water dip (HWD) and ethanol treatments resulted in increased acidity. Throughout the storage period, maximum acidity was maintained by HWD treatment followed by ethanol treatment. Karasahin et al. (2005) studied the effect of hot water dip on the acidity of egg-plant. They reported that titratable acidity increased after treatment at 40 °C for 3 min but during storage acidity decreased slightly. Mirdehghan et al. (2006) observed higher levels of both malic acid and citric acids in heat treated pomegranate. In ethanol treated sprouts higher acidity might be due to inhibition of metabolic activities. Similarly, Zavala et al. (2005) reported that postharvest application of ethanol resulted in higher acidity in strawberry fruits during storage. Similarly, Hagen et al. (2007) observed no significant changes in titratable acidity in apples treated with UV-B irradiation.

Non-enzymatic browning

Table 4 shows non-enzymatic browning of mung bean sprouts under various treatments during storage. All the

Table 3 Effect of different treatments on quality characteristics of mung bean sprouts during storage at room temperature and low temperature (T- Treatments; S- Storage; C.D.- Critical Difference)

Treatments	Period of storage (h)									
	Room temperature (25±1 °C)				Low temperature (7±1 °C)					
	0	24	48	Mean	24	48	72	96	120	Mean
Acidity (%) (n=3)										
Control	0.117	0.037	0.023	0.059	0.080	0.080	0.070	0.063	0.060	0.117
PEF	0.110	0.030	0.020	0.053	0.083	0.080	0.070	0.067	0.060	0.113
HWD	0.120	0.080	0.070	0.090	0.110	0.093	0.080	0.070	0.057	0.120
Ethanol	0.110	0.047	0.043	0.067	0.110	0.097	0.080	0.070	0.058	0.113
UV	0.113	0.033	0.033	0.060	0.080	0.080	0.070	0.057	0.053	0.113
Mean	0.114	0.045	0.038		0.080	0.080	0.070	0.063	0.060	0.117
C.D. at 5 %	T=0.004; S=0.003; T x S=0.007				T=0.003; S=0.004; T x S=0.006					

Table 4 Effect of different treatments on quality characteristics of mung bean sprouts during storage at room temperature and low temperature (T- Treatments; S- Storage; C.D.- Critical Difference)

Treatments	Period of storage (h)									
	Room temperature (25±1 °C)				Low temperature (7±1 °C)					
	0	24	48	Mean	24	48	72	96	120	Mean
Non-enzymatic browning (O. D. at 440 nm) (n=3)										
Control	0.012	0.022	0.036	0.023	0.016	0.017	0.026	0.033	0.036	0.023
PEF	0.017	0.039	0.051	0.035	0.018	0.018	0.025	0.031	0.038	0.024
HWD	0.025	0.055	0.075	0.051	0.025	0.029	0.034	0.039	0.045	0.033
Ethanol	0.014	0.016	0.019	0.016	0.015	0.016	0.021	0.027	0.030	0.020
UV	0.013	0.026	0.039	0.026	0.015	0.018	0.021	0.029	0.033	0.021
Mean	0.016	0.031	0.044		0.017	0.019	0.025	0.032	0.036	
C.D. at 5 %	T=0.002; S=0.001; T x S=0.004				T=N.S.; S=N.S.; T x S=N.S.					

treatments significantly increased the non-enzymatic browning of sprouts, except ethanol vapours treatment, where significantly lower browning was observed throughout the storage period. There was a progressive increase in non-enzymatic browning with increasing storage period. The effect of UV irradiation on enzymatic degradation of highly substituted cellulose acetate was investigated and It was found that cellulose acetate under UV irradiation for 30 days displayed 23 % weight loss in the sterilized 0.1 M acetate buffer (Arvanitoyannis 2010).

Total plate count (TPC)

UV light has been used to treat fruit-based products or juices (e.g., apple juice and cider) (Corbo et al. 2009). UV light is effective against microorganisms, and studies have shown that a treatment of less than 1 s is sufficient to kill molds and spores. Table 5 shows the microbial analysis of bean sprouts. There was a progressive increase in total plate count with increasing storage period at both the temperatures. However, there was no significant difference in total plate count under

various treatments. Total plate count under various treatments ranged from 3.32 to 4.08 log cfu/ml during storage period of 48 h at room temperature and from 3.56 to 3.99 log cfu/ml during storage period of 120 h at low temperature. However, several studies have been published on UV-C as a method to preserve the quality of different fruits and vegetables. The effect of short UV-C doses (0.4–8.14 kJ m²) in delaying senescence and deterioration and enhancing shelf-life of the fresh processed lettuce has been reported (Allende and Artes 2003). Lado and Yousef (2002) reported that UV-C radiation from 0.5 to 20 kJm⁻² inhibited microbial growth by inducing the formation of pyrimidine dimmers which alter the DNA helix and block microbial cell replication. Bibi et al. (2006) reported that the initial bacterial load in control carrot samples (*Daucus carota*) was 6.3×10² CFU/g in control samples and reached 6.5×10⁵ CFU/g after 14 days of storage. A dose of 1 kGy reduced the bioload down to 12.0 CFU/g, which were few colonies after 14 days storage. The samples receiving 2 kGy or higher doses were completely free of bacteria during 14 days refrigerated storage. The control samples showed 2.7×10¹ CFU/g fungal counts initially and increased to

Table 5 Effect of different treatments on quality characteristics of mung bean sprouts during storage at room temperature and low temperature (T- Treatments; S- Storage; C.D.- Critical Difference)

Treatments	Period of storage (h)					
	Room temperature (25±1 °C)			Low temperature (7±1 °C)		
	0	48	Mean	48	120	Mean
Total plate count (log cfu/ml) (<i>n</i> =3)						
Control	2.47	3.08	2.78	2.52	2.94	2.73
PEF	2.55	2.98	2.77	2.54	2.92	2.72
HWD	2.32	2.95	2.63	2.35	2.94	2.65
Ethanol	2.51	3.01	2.76	2.56	2.93	2.74
UV	2.44	3.08	2.76	2.47	2.99	2.73
Mean	2.46	3.02		2.49	2.94	
C.D. at 5 %	T=N.S.; S=0.08; T x S=N.S.			T=N.S.; S=0.09; T x S=N.S.		

Table 6 Effect of different treatments on quality characteristics of mung bean sprouts during storage at room temperature and low temperature (T- Treatments; S- Storage; C.D.- Critical Difference)

Treatments	Period of storage (h)									
	Room temperature (25±1 °C)				Low temperature (7±1 °C)					
	0	24	48	Mean	24	48	72	96	120	Mean
Sensory acceptability (score out of 9) (n=5 panelists)										
Control	8.0	7.2	6.5	7.3	7.9	7.9	7.5	7.5	7.0	7.6
PEF	8.0	7.0	6.2	7.0	7.9	7.5	7.5	7.0	6.5	7.4
HWD	8.5	7.8	7.0	7.7	8.3	7.9	7.7	7.6	7.2	7.9
Ethanol	8.1	7.9	7.5	7.8	8.5	7.9	7.9	7.3	7.3	7.9
UV	8.0	6.5	6.2	6.9	7.6	7.6	7.5	7.2	7.0	7.4
Mean	8.1	7.3	6.7		8.0	7.7	7.6	7.3	7.0	
C.D. at 5 %	T=0.2; S=0.1; T x S=0.4				T=0.2; S=0.2; T x S=0.4					

1.2×10⁴ CFU/g after 14 days of storage. The samples irradiated at a dose higher than 1 kGy were also completely fungi free during the two weeks storage at 5 °C. Bari et al. (2005) found that irradiation of broccoli and mung bean sprouts at 1.0 kGy resulted in reductions of approximately 4.88 and 4.57 log CFU/g, respectively, of a five-strain cocktail of *L. monocytogenes*.

Overall acceptability

There was a decrease in the score for overall acceptability with increasing storage period. Overall acceptability (on 9 point hedonic scale) under various treatments ranged from 8.5 to 6.2 during storage period of 48 h at room temperature and from 8.0 to 7.0 at 120 h of storage at low temperature. However, under both the storage temperatures, overall acceptability significantly increased by HWD and ethanol treatment, while a decrease was observed by PEF and UV-irradiation treatment (Table 6). It was also observed in the present investigation that the overall acceptability scores remained within the acceptable limits (≥6) upto 72 h at room temperature and 120 h at low temperature conditions. However, Bari et al. (2005) reported that the appearance, color, texture, taste, and overall acceptability of broccoli and mung bean sprouts, irradiated at 1.0 kGy, did not undergo significant changes after seven days of post-irradiation storage at 4 °C, in comparison with control samples. Arvanitoyannis et al. (2009) reviewed the impact of irradiation dose on the shelf life and microflora and sensory and physical properties of fish, shellfish, molluscs, and crustaceans; and observed that the shelf life prolongation of fish products was even 3–5 times longer than the traditionally employed methods. Bai et al. (2004) studied that the shelf life of ethanol and heat pretreated slices were 15 to 16 and 12 days, which was 7 and 3 to 4 days longer than that of non-pretreated controls (8 to 9 days), respectively, based on the visual observance.

Conclusions

It can be concluded from the findings of these studies that among all the treatments, ethanol vapours and HWD treatment were more effective in enhancing the shelf life of mung bean sprouts by suppressing the sprout length and weight. Ethanol treatment reduced the non-enzymatic browning, while HWD treatment increased the TSS and acidity of bean sprouts. Ethanol and HWD treatments inhibit decay development on the surface without affecting color & sensory quality during the storage. However, PEF and UV-irradiation treatments did not affect sprout length, TSS, non-enzymatic browning and sensory quality of bean sprouts significantly. In the light of the findings of this study and considering the potential of ethanol vapors in maintaining the keeping quality of sprouts, it could represent a promising alternative to conventional methods for other cut-fruits & vegetables also.

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