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Shelf-life evaluation of fresh white button mushrooms (*Agaricus bisporus*) using different moisture absorbers under refrigerated conditions

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ABSTRACT

Transpiration losses are the serious problem during the storage of mushrooms due to their high moisture content and possess the detrimental effect on the quality characteristics. Therefore, present investigation was aimed to overcome this problem using different desiccants (sorbitol, silica gel, citric acid and calcium chloride) at different concentrations under saturated condition within the packages. Highest total sugars, mannitol, total phenols, antioxidant potential and overall acceptability were found in mushroom packed with sorbitol (5 g/100g of mushroom). Similar treatment also resulted in lowest browning index, enzyme activity and microbial growth as compared to the others. It was further observed that, by the use of all the desiccants, a delay in veil opening and maturity index was observed as compared to control. As a whole, it was concluded that the shelf life of the fresh button mushrooms can be prolonged using sorbitol as a desiccant.

KEY WORDS: Desiccant, sorbitol, silica gel, moisture sorption, transpiration loss, maturity index.

1. INTRODUCTION

Nutrition is the most important subject for humankind and nutritional values of foods play an important role in human health (Caglarirmak, 2011). Mushrooms represent one of the world's greatest untapped resources of nutritious food (Afiukwa, 2013) as they are rich in protein, minerals, vitamins; fibers and contain an abundance of essential amino acids (Sadler, 2003) and is also known as diabetic delight (Rai and Arumuganathan, 2008). They are also known to possess promising antioxidative, cardiovascular, hypercholesterolemia, antimicrobial, hepatoprotective and anticancer effects (Khatun, 2012).

But the major problem with mushrooms is their high moisture content making it highly perishable that they start deteriorating immediately within a day after harvest (Gupta, 2015), resulting in a large amount of water vapor accumulating inside the package, thereby increasing the in-package humidity level (Mahajan, 2008) providing barrier properties for their storage and ultimately decreases their commercial value (Gupta, 2015). Mushrooms after harvest they often change in ways that make them unacceptable for human consumption (Ioannou and Ghoul, 2013). Washing of mushrooms to remove adhering compost or casing residues produces an attractive product for fresh market but may accelerate browning or development of purple blotches (Sapers, 1994). Postharvest browning of mushrooms is a severe problem that reduces the shelf life because of respiration and biochemical activities. The high tyrosinase and phenolic content of mushrooms makes them prone to enzymatic browning which is the major cause of quality loss and accounts for reduction in their market value (Brennan, 2000).

Owing to the highly perishable nature of mushrooms and gluts at the time of harvest, ways and means of its preservation have assumed importance. Therefore, appropriate storage conditions are needed to extend their marketability and availability in fresh form and to prevent their deterioration and senescence after harvest (Taghizadeh, 2010). Hence, assessment of different post harvest handling methods is an indispensable prerequisite (Tibuhwa, 2012).

Polymeric films used in fruit and vegetable packaging have lower water vapour transmission rates relative to the transpiration rates of fresh products. This leads to saturated conditions within the packages (Hardenburg, 1990). High humidity conditions prevail in the packages, causing moisture condensation, microbial growth and decay of the product (Cliffe-Byrnes and O'Beirne, 2007). The use of moisture absorbers such as sorbitol, sodium chloride, propylene glycol and polyvinyl alcohol have resulted in better color of the mushrooms (Roy, 1995; Anantheswaran and Sunkara, 1996; Roy, 1996; Villaescusa and Gil, 2002). The recommended levels of relative humidity for storage of fresh produce represent a delicate balance between desiccation of the commodity by low humidity and increased decay by high humidity (Hardenburg, 1986). Mushrooms packaged along with certain moisture adsorbers like silica gel, sorbitol and $CaCl_2$ wrapped in polyethylene help in decreasing the microbial growth and in increasing the shelf life. Koushki (2011) evaluated that MAP in combination of $CaCl_2$ dipping was effective in extending shelf life of the packaged mushrooms. Shirazi (1989) used different moisture adsorbers to lower the RH of packages containing green tomato. Various moisture adsorbers have been used in combination to maintain the RH within the packets of mushrooms but till date the individual effect of various moisture adsorbers at different concentrations have not been observed. The present research is an effort to use different desiccants at different concentrations to maintain the quality of fresh mushrooms.

2. MATERIALS AND METHODS

Material: Freshly harvested button mushrooms were made available by the Department of Plant Pathology, SKUAST-J. The research was conducted in the Department of Food Science and Technology, SKUAST-J. Different moisture adsorbers required for research were bought from Megazymes, Pro Lab Marketing Private Ltd., New Delhi.

Experimental: Mushrooms of uniform size and intact veil were selected, washed with tap water to remove dust and dirt; surface dried and packed in LDPE (Low Density Polyethylene) pouches along with different desiccants i.e. silica gel (3 g and 5 g per 100 g mushroom), sorbitol (5 g and 10 g per 100 g mushroom), citric acid (3 g and 5 g per 100 g mushroom) and calcium chloride (1 g and 3 g per 100 g mushroom) respectively. The mushroom packets along with these desiccants so prepared were stored under refrigerated conditions to assess their effect on quality characteristics.

Analysis:

Physiological analysis: The maturity index was measured on the basis of scale ranging from 1 (veil intact) to 7 (cap open, gills flat) as suggested by Guthire (1984). Veil opening rate was defined as the ratio of the number of mushrooms with cap opening out to the total number of mushrooms (Lagnika, 2011). Randomly, six mushrooms were taken from a packet and were evaluated manually by visual observation. Physiological weight loss was determined by weighing the contents of the package before and after storage and was expressed as the percent loss of weight with respect to the initial weight (Lagnika, 2011).

$$\text{Weight loss (\%)} = \frac{W_i - W_f}{W_i}$$

Where, W_i is the initial weight of the mushrooms before treatment, and W_f is the final weight of mushrooms after storage.

The surface colour of mushrooms was measured with the help Hunter Lab Mini Scan XE Colorimeter with an 8-mm-diameter diaphragm calibrated with a white tile (X = 81.1, Y = 86.0 and Z = 91.8) (Simon and Gonzalez-Fandos, 2009). Where, L* indicates (whiteness/ darkness), a* (greenness/ redness) and b* (yellowness/ blueness). Each treatment was replicated thrice for colour measurement. The browning index was calculated using the following expression (Bozkurt and Bayram, 2006).

$$BI = 100 \times \left[\frac{X - 0.31}{0.71}\right]$$

Where, $$X = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)}$$

Physico-chemical and Phyto-chemical analysis: Total sugars were determined by anthrone method as per the standard procedure described by Sadasivam and Manickam (2008) using glucose as standard. Sugar alcohol (mannitol) was estimated by the method given by Stoop and Mooibroek (1998) with some modifications. The total phenols content were determined by Folin Ciocalteu procedure as given by Sadasivam and Manickam (2008) using gallic acid as standard. Antioxidant potential was determined by ferric-reducing antioxidant power assay (FRAP) according to the standard method as described by Alvarez-Parrilla (2007) with some modifications. FRAP reagent was prepared daily by mixing 0.3 mM acetate buffer (pH 3.6) with 10 mM 2,4,6-tripyridyl-s triazine (TPTZ) solution in 40 mM HCl and 20 mM $FeCl_3 \cdot 6H2O$ (10:1:1 ratio). The combination of all these is called FRAP reagent. An amount of 1.8ml freshly prepared FRAP reagent was taken in a test tube and incubated at 30°C in water bath for 10 minutes. Then absorbance was taken at 0 minute (t_o). Immediately 100µl of sample extract and 100µl of methanol was added to the test tube, mixed and incubated at 30°C for 30 minutes. The absorbance was taken at 593 nm. Ferrous sulphate was used as a standard curve. The antioxidant potential of the sample extract was determined against a standard curve of ferrous sulphate and the frap value was expressed as µmol Frap/g of extract and calculated using the following equation:

FRAP value = Absorbance (sample + FRAP reagent) – Absorbance (FRAP reagent)

Microbial Analysis: Different samples of mushroom stored with different desiccants was analysed for total plate count using nutrient agar (NA) and recorded as $cfuml^{-1}$ (Nwachukwo and Ezeigbo, 2013). The medium used for the all the microbial tests were procured from Himedia Laboratories Private Ltd., Mumbai, India.

Sensory Analysis: Different samples of mushroom stored with different desiccants were subjected to sensory evaluation after 3 days interval using 9-point hedonic scale as described by Joshi, (2006). The sensory evaluation was performed by a panel of 10 semi trained judges (the panel members were given a pre idea about sensory attributes of mushroom).

Statistical analysis: The results obtained from physiological, phytochemical and physiological attributes were subjected to analysis of variance using a completely randomized design (CRD) and the means with critical differences have been reported. The statistical analysis of the data obtained from sensory evaluation was done by Randomized Block Design (RBD) as given by Cochran and Cox (1963).

3. RESULTS AND DISCUSSION

Among the different desiccants used weight loss was found to be highest in $CaCl_2$ treated samples due to high moisture retaining capacity of $CaCl_2$ and the least weight loss was observed in control though different desiccants used were helpful in preventing condensation inside the package. As the desiccants have water retaining property addition of these desiccants inside the package containing mushrooms increased the weight loss.

On 3rd day of storage, the highest weight loss (1.30 %) was observed in T_8 ($CaCl_2$, 3g) and the lowest weight loss (0.73 %) was observed in control. As the storage period advanced, mean value for weight loss increased from 0.91 percent on 3rd day to 1.51 percent on 9th day of storage. Our results are in agreement with Anantheswaran and Sunkara (1996) and Mahajan (2008) who studied that mushrooms in control treatment (without moisture adsorber) lost the least amount of weight after 3, 6 and 9 days of storage when compared with sorbitol, $CaCl_2$, KCl, silica gel and clay. A weight loss of 3.8% was obtained in the package with 1 g of CaOH used as a CO_2 scavenger with 100 g of sliced mushrooms (Olivera, 2012). It is evident from Fig.2 that weight gain by desiccants differed significantly in all the treatments as well as during storage. On 3rd day of storage, the highest weight gain of 2.62 g water g^{-1} desiccant was recorded in T_7 ($CaCl_2$, 1g) and the lowest of 0.26 g water g^{-1} desiccant was recorded in T_1 (silica gel, 3g). On 9th day of storage, the highest weight gain of 8.0 g water g^{-1} desiccant was recorded in T_8 ($CaCl_2$, 3g) whereas, the lowest of 0.72 water g^{-1} desiccant in T_1. All the desiccants turned soggy up till 9th day of storage.

However, not only water shortage but also excess moisture can cause stress in the harvest commodity. Water-excess stress is most evident when moisture is allowed to accumulate on the produce surface, usually as a result of water condensation. Condensation hastens spoilage and considerably shortens shelf life (Hemalatha and Kleinhenz, 2000). The maturity index of mushrooms was found to increase with storage and the highest maturity index was observed in case of $CaCl_2$. Mushrooms packaged with various desiccants observed the lowest cap opening as compared to control (Table.1). On 3rd day, the highest (2.40) maturity index given on the basis of scale ranging from (1-veil intact to 7-cap open, gills flat) was recorded in control and the lowest (1.10) in T_1 (silica gel, 3g) which reached to 4.87 in control and 2.64 in T_1on 9th day of storage. This might be due to natural senescence and respiration. Tomatoes packaged with 10g $CaCl_2$ lost 16% of their fresh weight over 48 days of storage and shriveled severely (Shirazi and Cameron, 1992).

The total phenol, antioxidant potential, total sugars and mannitol content decreased with storage. The decrease in control was more as compared to samples treated with desiccants and it might be due to natural senescence and respiration process occurring in mushrooms. As mushrooms age, they lose their whiteness and turned brown. Brown coloration was uneven because it occurs where mushrooms cells are damaged. Desiccants helped in retaining the whiteness of mushrooms up to 9 days and those packed with sorbitol and silica gel had better appearance as compared to control which might be because of prevention of condensation inside the package. Roy (1995; 1996) and Anantheswaran and Sunkara (1996) also observed that the use of moisture adsorbers such as sorbitol, NaCl, propylene glycol and polyvinyl alcohol have resulted in better color of the mushrooms.

On the basis of sensory evaluation, overall acceptability decreased with storage and mushrooms packed with sorbitol attained highest acceptability. The decrease might be because of onset of senescence. Mushrooms packed with $CaCl_2$ retained more firmness as compared to other desiccants like citric acid, sorbitol. Less tough mushrooms responded better to the treatments than did the tough mushrooms. Although no off–odor was noticed in mushrooms packed with different desiccants. Villaescusa and Gill (2003) reported that *Pleurotus* mushrooms when packed under modified conditions along with silica gel showed no change in aroma and odor up to 7 days at 4°C. Deell (2006) examined the effect of sorbitol containing sachets on the quality of broccoli stored in modified atmosphere packaging in the presence of $KMNO_4$.

Desiccants reduced microbial spoilage as compared to control which might be due to reduced condensation inside the package. The addition of natural clay adsorbent almost eliminates condensation in raspberry packages and reduces decay (Toivonen, 2002). Among the various desiccants citric acid was the most effective in controlling bacterial growth due to its antimicrobial and chelating effect. Sorbitol and silica gel also controlled microbial growth by maintaining the humidity inside the package. Shirazi and Cameron (1992) demonstrated that control of RH in tomato packages using micro porous sachets containing sorbitol, xylitol, NaCl extended the storage life mainly by retarding surface mold development.

Under ambient conditions mushrooms packed with desiccants have a shelf life of not more than a day which might be due to increased condensation, high transpiration rate and low relative humidity inside the package at high temperature, leading to wilted appearance, loss of freshness and quality deterioration. The desiccants also turned soggy and became liquid at higher temperature after a day, giving watery appearance and hence, could not be used further. Song (2001) also reported the moisture sorption kinetics of xylitol and sanwet at 15 and 25°C and showed that the moisture sorption increased with increased temperature.

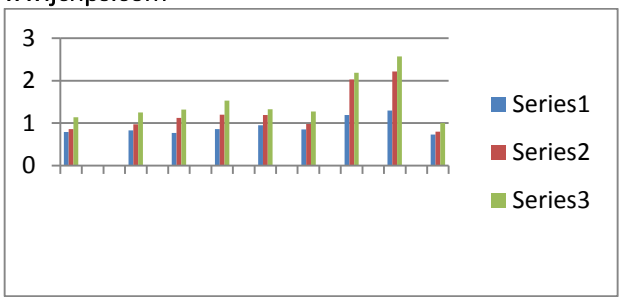

Fig.1.Effect of different desiccants on the physiological weight loss of mushrooms stored under refrigerated condition.

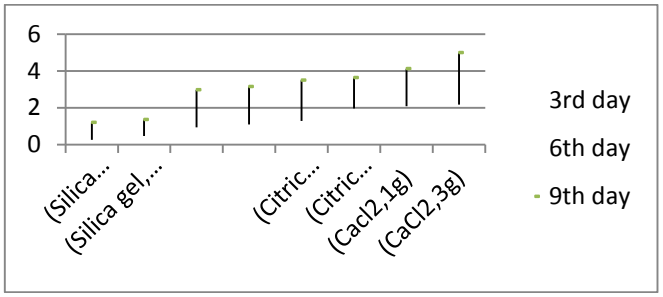

Fig.2.Weight gain by desiccants (g water g^{-1} desiccant) in mushrooms stored under refrigerated condition.

Table.1. Effect of different desiccants on the maturity index of mushrooms stored under refrigerated condition

Treatment	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	1.10	2.13	2.64	1.95
T_2 (Silica gel, 5g)	1.27	2.33	2.82	2.09
T_3 (Sorbitol, 5g)	1.23	2.20	2.73	2.15
T_4 (Sorbitol, 10g)	1.34	2.45	3.15	2.31
T_5 (Citric acid, 3g)	1.63	2.52	3.29	2.48
T_6 (Citric acid, 5g)	1.85	2.70	3.44	2.66
T_7 ($Cacl_2$, 1g)	2.19	2.84	3.68	2.90
T_8 ($CaCl_2$, 3g)	2.26	3.12	4.12	3.16
T_9 (Control)	2.40	3.52	4.87	3.59
Mean	1.69	2.64	3.39	

All values are mean significant values, C.D (p=0.05), Treatment = 0.09, Storage = 0.05, T x S= 0.16

Table.2. Effect of different desiccants on antioxidant potential (µmol Frap /g f. wt.) of mushrooms stored under refrigerated condition

Treatments	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	2.04	1.15	0.52	1.51
T_2 (Silica gel, 5g)	2.15	1.38	0.86	1.68
T_3 (Sorbitol, 5g)	2.17	1.87	1.12	1.88
T_4 (Sorbitol, 10g)	1.96	1.20	0.77	1.57
T_5 (Citric acid, 3g)	1.82	0.95	0.56	1.44
T_6 (Citric acid, 5g)	1.69	0.76	0.52	1.33
T_7 ($Cacl_2$, 1g)	1.49	0.62	0.37	1.21
T_8 ($CaCl_2$, 3g)	1.18	0.59	0.23	1.09
T_9 (Control)	1.76	1.05	0.47	1.41
Mean	1.80	1.06	0.60	

All values are mean significant values, C.D (p=0.05), Treatment = 0.08, Storage = 0.05, T x S= 0.20

Table.3. Effect of different desiccants on phenols (mg/g f.wt.) of mushrooms stored under refrigerated condition

Treatment	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	0.96	0.93	0.70	0.86
T_2 (Silica gel, 5g)	1.03	0.90	0.88	0.94
T_3 (Sorbitol, 5g)	1.07	1.01	0.93	1.00
T_4 (Sorbitol, 10g)	0.95	0.77	0.60	0.77
T_5 (Citric acid, 3g)	0.99	0.71	0.43	0.71

T_6 (Citric acid, 5g)	0.90	0.70	0.50	0.70
T_7 ($Cacl_2$, 1g)	0.82	0.55	0.44	0.60
T_8 ($CaCl_2$, 3g)	0.84	0.54	0.40	0.59
T_9 (Control)	0.77	0.41	0.36	0.51
Mean	0.93	0.72	0.58	

All values are mean significant values, C.D (p=0.05), Treatment = 0.10, Storage = 0.06, T x S= 0.16

Table.4. Effect of different desiccants on total sugars (g/100g f.wt.) of mushrooms stored under refrigerated condition

Treatment	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	1.12	1.09	0.73	0.98
T_2 (Silica gel, 5g)	1.15	1.07	1.01	1.08
T_3 (Sorbitol, 5g)	1.16	1.13	1.10	1.13
T_4 (Sorbitol, 10g)	1.09	1.00	0.65	0.91
T_5 (Citric acid, 3g)	0.97	0.77	0.70	0.81
T_6 (Citric acid, 5g)	0.90	0.88	0.82	0.87
T_7 ($Cacl_2$, 1g)	0.74	0.61	0.49	0.61
T_8 ($CaCl_2$, 3g)	0.87	0.85	0.53	0.75
T_9 (Control)	0.72	0.56	0.46	0.58
Mean	0.97	0.88	0.72	

All values are mean significant values, C.D (p=0.05), Treatment = 0. 90, Storage = 0.05, T x S= 0.16

Table.5. Effect of different desiccants on mannitol (g/100g f.wt.) of mushrooms stored under refrigerated condition

Treatment	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	1.02	0.98	0.96	0.99
T_2 (Silica gel, 5g)	1.10	1.01	0.97	1.03
T_3 (Sorbitol, 5g)	1.12	1.05	1.00	1.06
T_4 (Sorbitol, 10g)	1.06	1.01	0.94	1.00
T_5 (Citric acid, 3g)	1.08	1.02	0.97	1.02
T_6 (Citric acid, 5g)	1.05	1.00	1.03	1.03
T_7 ($Cacl_2$, 1g)	1.00	0.96	0.92	0.96
T_8 ($CaCl_2$, 3g)	0.98	0.94	0.90	0.94
T_9 (Control)	0.99	0.95	0.88	0.94
Mean	1.04	0.99	0.95	

All values are mean significant values, C.D (p=0.05), Treatment = N.S, Storage = 0.05, T x S= N.S

Table.6. Effect of different desiccants on the PPO (Ug^{-1} f. wt.) activity of mushrooms stored under refrigerated condition

Treatments	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	15.84	21.29	27.46	18.23
T_2 (Silica gel, 5g)	13.86	18.72	24.68	16.40
T_3 (Sorbitol, 5g)	13.13	17.50	22.38	15.33
T_4 (Sorbitol, 10g)	14.60	18.38	25.63	16.73
T_5 (Citric acid, 3g)	14.86	19.95	24.59	16.93
T_6 (Citric acid, 5g)	16.74	22.52	27.63	18.80
T_7 ($Cacl_2$, 1g)	18.80	25.68	28.45	20.31
T_8 ($CaCl_2$, 3g)	17.26	28.46	31.57	25.76
T_9 (Control)	17.34	26.22	37.92	27.16
Mean	15.82	22.08	27.81	

All values are mean significant values, C.D (p=0.05), Treatment = 0.08, Storage = 0.05, T x S= 0.20

Table.7. Effect of different desiccants on the color of mushrooms stored under refrigerated condition

Treatments		Storage period (days)			
		3	6	9	Mean
T_1 Silica gel (3g)	L*	85.48	83.97	81.79	83.75
	a*	0.87	1.26	1.48	1.20
	b*	10.54	16.68	29.56	18.93
T_2 Silica gel (5g)	L*	86.29	84.76	81.46	84.17
	a*	0.65	1.18	1.53	1.12
	b*	10.24	17.64	25.68	17.95
T_3 Sorbitol (5g)	L*	85.63	83.84	81.76	83.74
	a*	0.59	1.09	1.58	1.09
	b*	9.76	15.82	23.42	16.33
T_4 Sorbitol (10g)	L*	84.66	82.14	80.63	82.48
	a*	0.94	1.38	1.89	1.40
	b*	11.97	18.82	27.71	19.17
T_5 Citric acid (3g)	L*	84.51	81.92	80.15	82.19
	a*	0.54	1.59	2.18	1.44
	b*	12.65	21.92	27.17	20.58
T_6 Citric acid (5g)	L*	84.72	81.81	79.77	82.10
	a*	0.76	1.76	2.13	1.55
	b*	13.86	19.56	30.53	21.32
T_7 $Cacl_2$ (1g)	L*	83.37	80.67	77.82	80.62
	a*	1.16	1.87	2.36	1.80
	b*	13.83	22.88	32.21	22.97
T_8 $CaCl_2$ (3g)	L*	84.32	81.28	78.28	81.29
	a*	1.27	2.18	2.84	2.10
	b*	13.33	22.22	29.95	21.83
T_9 Control	L*	83.23	80.59	77.67	80.50
	a*	1.29	2.56	3.19	2.35
	b*	15.66	24.29	37.28	25.71
Mean	L*	84.69	82.33	79.93	
	a*	0.90	1.65	2.13	
	b*	12.42	19.98	29.17	

All values are mean significant values, **L* (Whiteness/darkness), a* (redness/greenness), b* (yellowness/ blueness),** (p=0.05)

Table.8. Effect of different desiccants on the browning index of mushrooms stored under refrigerated condition

Treatments	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	3.25	5.44	10.77	6.49
T_2 (Silica gel, 5g)	3.09	5.70	9.18	5.99
T_3 (Sorbitol, 5g)	2.95	5.12	8.23	5.43
T_4 (Sorbitol, 10g)	3.76	6.39	10.24	6.80
T_5 (Citric acid, 3g)	3.90	7.63	10.13	7.22
T_6 (Citric acid, 5g)	4.33	6.81	11.72	7.62
T_7 ($Cacl_2$, 1g)	3.65	8.21	12.95	8.27
T_8 ($CaCl_2$, 3g)	4.29	7.95	11.87	8.04
T_9 (Control)	5.15	8.02	15.82	9.66
Mean	3.82	6.81	11.21	7.28

All values are mean significant values, C.D (p=0.05), Treatment = 0.09, Storage = 0.05, T x S= 0.16

Table.9. Effect of different desiccants on the overall acceptability of mushrooms stored under refrigerated condition

Treatments	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	7.58	7.08	6.51	7.06
T_2 (Silica gel, 5g)	7.72	7.21	6.64	7.19
T_3 (Sorbitol, 5g)	7.77	7.32	6.66	7.25
T_4 (Sorbitol, 10g)	7.47	6.94	6.42	6.94
T_5 (Citric acid, 3g)	7.41	6.90	6.40	6.90
T_6 (Citric acid, 5g)	7.33	6.79	6.32	6.81
T_7 ($Cacl_2$, 1g)	7.14	6.69	5.81	6.55
T_8 ($CaCl_2$, 3g)	7.00	6.28	5.65	6.31
T_9 (Control)	6.79	6.17	5.44	6.13
Mean	7.36	6.82	6.21	

All values are mean significant values, C.D (p=0.05), Treatment = 0.05, Storage = 0.09, T x S= 0.16

Table.10. Effect of different desiccants on the total plate count (c.f.u/g) of mushrooms stored under refrigerated condition

Treatments	Storage period (days)			
	3	6	9	Mean
T_1 (Silica gel, 3g)	4.1	7.2	9.0	6.76
T_2 (Silica gel, 5g)	3.9	5.4	8.6	5.96
T_3 (Sorbitol, 5g)	3.5	4.6	7.8	5.30
T_4 (Sorbitol, 10g)	4.9	5.8	8.1	6.26
T_5 (Citric acid, 3g)	3.1	4.8	6.9	4.93
T_6 (Citric acid, 5g)	2.8	5.0	7.1	4.96
T_7 ($Cacl_2$, 1g)	5.5	7.3	8.8	7.20
T_8 ($CaCl_2$, 3g)	5.1	6.5	9.5	7.03
T_9 (Control)	5.6	7.8	9.7	7.70
Mean	4.27	6.04	8.38	

All values are mean significant values, C.D (p=0.05), Treatment = 0.20, Storage = 0.11, T x S= 0.35

4. CONCLUSION

In- package desiccants viz: silica gel, sorbitol, citric acid and $CaCl_2$ were significant in preventing condensation inside the package and thus, in reducing microbial growth and extending shelf-life. These desiccants helped in delaying veil opening and maturity index as compared to control. In-package desiccant T_3 (sorbitol, 5g/100g) was the most effective in lowering browning index (5.43), enzyme activity (15.33Ug^{-1}) whereas total sugars (1.13g/100g), mannitol (1.06g/100g), total phenols (1.0mg/g) and antioxidant potential (1.88µmol) were found to be the highest. However with storage, the browning index and enzymatic activity increased and on the other hand the total sugars, mannitol, total phenols and antioxidant potential decreased. On the basis of overall acceptability treatment T_3 (sorbitol, 5g/100g) was designated to be the best treatment. However with storage, all the sensory parameters viz: appearance, flavor, texture and taste decreased. Mushrooms kept with various in-package desiccants and stored under ambient conditions got spoiled after one day.

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