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RESEARCH ARTICLE

SHELF LIFE AND STORAGE QUALITY OF WHITE BUTTON MUSHROOMS (*AGARICUS BISPORUS*) AS AFFECTED BY PACKAGING MATERIAL.

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Abstract

Mushrooms are highly perishable in nature and deteriorate within a day after harvesting due to their high respiration rate and delicate epidermal structure. Consequently, the shelf-life of freshly harvested mushrooms is limited to 1-3 days at ambient condition. Therefore, present study was conducted to investigate effect of packaging materials viz., polypropylene, low density polyethylene, commercially used packages and paper punnets with shrink wrapping on quality of fresh white button mushroom. The freshly harvested mushrooms were washed in different solutions of $CaCl_2$, KMS and NaCl, then packed with different packaging materials and stored at ambient (22+2° C) and refrigerated (4+2° C) conditions. The mushroom packed in polypropylene after washing with 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl had good retention of colour, texture after 3 days of storage at both ambient and refrigerated conditions. Weight loss occurred in all packages after 3 days of storage, which was higher at ambient condition as compared to refrigerated condition. A gradual decrease in the total phenolic content of packed mushroom was recorded with increase in the storage interval. While on the basis of colour and texture the mushroom treated as above and stored at refrigerated condition was acceptable up to 6 days of storage. Hence, polypropylene could be successfully used for packing of fresh mushrooms to increase their shelf-life as well as to maintain their quality during storage.

Introduction:-

Mushrooms represent a most conspicuous group of higher fungi. Food and Agricultural Organization (FAO, 2006) of the United Nations has recommended mushrooms as supplementary food to the growing population of the developing countries where cereals constitute staple diet. Mushrooms are mainly marketed in fresh form. Their commercial value decreases within 2-3 days after harvest owing to senescence, water loss, microbial attack and browning (Nerya *et al.*, 2006). In comparison of other vegetables and fruits, the respiration rate (200 to 500 mg/kg h at 20° C) of mushrooms is relatively higher, which is related to their thin and porous epidermal structure (Kim *et al.*, 2006). Therefore, they cannot be stored for more than 24 hours at ambient conditions and has to be marketed in

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fresh form. Thus, quality control during post-harvest period is very important to maintain the acceptability of fresh produce of mushrooms with varying post-harvest practices.

Modified-atmosphere (MA) packaging is one of the recent technologies developed to increase the shelf-life of mushrooms (Ares *et al.*, 2006). Sveine *et al.* (1967), Nichols and Hammond (1973), Roy *et al.* (1995), Tano *et al.* (1999) and Kim *et al.* (2006) have also reported that MA packaging is the most economical and efficient method to prolong storage life of mushroom due to reduced oxygen levels. The composition of modified atmosphere inside the package depends on various factors such as the amount of product, respiration rate, proportion of the amount of product to film surface area, permeability of film to gases, and storage temperature (Simon *et al.*, 2010). Modified atmospheres, richer in CO_2 and poorer in O_2 than air, are assumed to decline the respiration rate, decay and physiological deteriorations of vegetables resulting in the extension of shelf-life (Antmann *et al.*, 2008). Therefore, the present study was conducted to investigate the effect of different packaging materials on the physicochemical parameters of white button mushroom stored at ambient and refrigerated conditions.

Materials and Methods:-

Sample collection:-

Fresh picked, unwashed, whole white button mushrooms, used in this study were procured from Mushroom Center, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan. After harvesting, they were sorted out for any damage or discolouration, and after it their stems were cut.

Fresh unwashed mushroom was observed to contain 90.20 + 0.03 % of moisture while the average pH value assessed in fresh mushroom was 6.85 + 0.02. The average optical density to measure the degree of whiteness of fruit bodies of unwashed mushroom measured at 420 nm was recorded as 0.610 + 0.01 while the total phenols was recorded as 0.44 + 0.02 %.

Washing treatment:-

The sorted, unwashed mushrooms were given three different washing treatments viz., plain water washing (T_1, control), 0.5 % KMS (T_2) and 0.5 % KMS + 0.5 % NaCl + 0.5 % $CaCl_2$ (T_3) for 2 min to remove the adhering casing soil and then placed on the absorbent paper to remove excess surface water.

Packaging and storage:-

After the washing treatment mushrooms (about 200+1 g) were packed in four different packaging materials viz., polypropylene bag (PP, 1500 gauze), low density polyethylene bag (LDPE, 200 gauze), commercially used packages (obtained from the market which is commonly used by the local growers and whose thickness was unknown) and paper punnets with shrink wrapping and sealed as shown in Fig. 1. The packed mushrooms were then stored at two different conditions i.e. at ambient (22+2° C) and refrigerated (4+2° C). The mushrooms were then analyzed for various physico-chemical changes and sensory attributes at the interval of 3 days viz., 0, 3, 6, 9 days.

Quality Parameters:-

Weight loss (%):-

Weight loss in mushroom packed in different packaging materials was calculated by deducting the weight of mushroom after storage from the initial weight of mushroom i.e. before storage. The results were expressed as per cent weight loss in mushroom.

$$\text{Weight loss by mushroom (\%)} = \frac{\text{(Initial weight of sample} - \text{Final weight of sample)}}{\text{Initial weight of sample}} \times 100$$

Moisture content:-

The moisture content was estimated by drying the weighed sample (5 g) to a constant weight in hot air oven at 70+2° C. The dried samples were then cooled to room temperature in a desiccator prior to weighing (Ranganna, 2010). Loss in weight of sample after drying representing the moisture content was expressed as per cent (w/w).

$$\text{Moisture content (\%)} = \frac{\text{(Weight of fresh sample} - \text{Weight of dried sample)}}{\text{Weight of fresh sample}} \times 100$$

Total phenols:-
The amount of total phenols in the mushroom sample was determined with the Folin-Ciocalteu reagent using catechol as a standard (Bray and Thorpe, 1954). One gram of sample was taken and grinded with 10 ml of 80 % ethanol in pestle and mortar, and centrifuged for 20 min at 1000 rpm and filtered. Filtrate was evaporated in oven up to dryness and dried extract was dissolved in 5 mL distilled water. 0.2-2.0 mL aliquot was taken in separate test tubes and volume was made up to 3 mL. Then 0.5 mL Folin-Ciocalteu reagent was added. After 3 min 2 mL of Na_2CO_3 (20 %) was added and mixed. Test tubes were placed in boiling water bath for 1 min and then cooled. Optical density of the sample was recorded at 650 nm with the help of spectrophotometer (Spectronic 20D). The concentration was determined from the standard curve prepared using different concentrations of catechol (8- 32 µg/mL) using the above procedure. The results were expressed as mg per 100 g on fresh weight basis and calculated as given below:

$$\text{Total phenols (\%)} = \frac{\text{O D of unknown sample} \times \text{Phenol value from standard curve (µg)} \times \text{Total volume of extract} \times 100}{\text{Aliquot of sample used} \times \text{Weight of sample taken} \times 1000 \times 1000}$$

Degree of whiteness (Colour):-
The known weight of sample was macerated with distilled water and then filtered. The increase in absorbance of sample extract at 420 nm as per method was taken. Optical density of filtrate was measured by spectrophotometer (Spectronic 20D), using distilled water as a blank (Ranganna, 2010).

pH:-
The sample of mushroom was crushed with an equal quantity of distilled water and the pH was determined using digital pH meter after calibration with standard buffers of 4, 7 and 9 (Ranganna, 2010).

Visual observation:-
The colour and texture of the washed as well as stored mushroom were analyzed through sensory observation i.e. colour through visual observation whereas texture by the hand feel or sense of touch.

Statistical analysis:-
The data of the experimental observations during the above studies were computed for analysis of variance (ANOVA) using STATISTICA version 7 software of StatSoft Inc., Tulsa, Oklahoma, USA. The ANOVA was performed as per the completely randomized design (CRD). Experiment conducted in this study was replicated thrice.

Results and Discussion:-

Weight loss:-
The data on weight loss is shown in Fig. 1 reveals that minimum weight loss was observed in mushrooms treated with 0.5 % KMS + 0.5 % NaCl + 0.5 % $CaCl_2$ solution which may probably be due to the $CaCl_2$ treatment as calcium helps in maintaining the cellular organization and regulating enzyme activities, thereby reducing moisture loss associated with senescence (Jones and Lunt, 1967). The loss in weight with increment in storage duration and temperature had also been reported by (Antmann *et al.*, 2008; Tano *et al.*, 2007 and Villaescusa and Gil, 2003), corresponding to fall in vapour transmission of films, transpiration and respiration rate of the mushrooms (Roy *et al.*, 1995) irrespective of the treatment and packaging materials.

Among packaging materials, the maximum weight loss was observed in paper punnet with shrink wrapping (PPSW) followed by commercially used package (CU) and minimum in polypropylene (PP) irrespective of the washing treatment given to the mushroom. Mushroom stored at refrigerated condition had highest weight than the mushroom stored under ambient condition. This agreed with the findings of Burton and Noble (1993) who observed that weight loss from mushroom stored in open punnets at either 5° C (73 % RH) or 18° C (90 % RH) were linear, averaging 4 % per day at 5° C and 6 % per day at 18° C.

Moisture Content:-
A decrease in moisture content was noticed with the advancement of storage period in all the packaging materials irrespective of the storage conditions at which they were kept (Table 1). This could be attributed to the fact that

mushrooms have a thin and porous epidermal structure, which is prone to quick superficial dehydration that causes significant quality losses (Singer, 1986). The maximum decrease in moisture content was recorded in T_1 i.e. plain water washing followed by T_2 (0.5 % KMS) and T_3 (0.5 % KMS + 0.5 % NaCl + 0.5 % $CaCl_2$). Mushroom packed with PPSW showed maximum reduction in moisture content when compared to other packaging materials, irrespective of the washing treatment given to them. The table clearly shows that the retention of moisture was best in mushrooms packed with PP after 3 days of storage at both temperatures. Antmann *et al*. (2008) reported that unpacked mushrooms show a weight loss of 72 % after 6 days of storage, suggesting that dehydration is a major factor for loss in mushroom quality during storage. The mushrooms stored at refrigerated conditions were better preserved than at ambient conditions, which was in accordance with Babitha and Kiranmayi (2010) who reported that tomatoes stored at refrigerated temperature had significantly higher moisture content than at ambient conditions at the first day of storage.

Total phenols:-

Data on total phenol content of packed white button mushroom during storage are presented in Table 2. A significant decrease was recorded in the total phenol content with increase in the storage interval at both ambient and refrigerated conditions. The decrease in bioactivity of phenols may be attributed to their ability to chelate metals, inhibit lypoxgenase, and scavenge free radicals (Mallavadhani *et al.*, 2006; Carmen and Xin, 2004). The maximum decrease in the total phenols was recorded in mushroom washed with plain water (T_1) when compared with mushroom washed with 0.5 % KMS (T_2) and 0.5 % KMS + 0.5 % NaCl + 0.5 % $CaCl_2$ (T_3). Among packaging materials, the phenolic content was observed to decrease less in mushroom packed in PP and maximum in PPSW. Altunkaya and Gokmen (2008) further reported that decrease in total phenol content may be probably due to the oxidation by polyphenol oxidase (PPO) during the storage of mushrooms.

Degree of whiteness (Colour):-

The amount of colour change depends upon the storage time and temperature. The copper containing enzymes tyrosinase, of the PPO group is largely responsible for the enzymatic discolouration of mushrooms (Nerya *et al*., 2006). The degree of browning in mushrooms increased rapidly during the time of storage (Fig. 2). The change in colour was more prominent in mushroom stored at ambient temperature as compared to mushroom stored at refrigerated temperature. The maximum browning was observed in mushroom with plain water washing and minimum in T_3 (0.5 % KMS + 0.5 % NaCl + 0.5 % $CaCl_2$). After 3 days of storage at refrigerated condition it was observed that mushrooms packed in PP has the lowest discolouration as compared to other packaging materials. The results were in agreement with results of Lopez-Briones *et al*. (1993) who reported that packaging of button mushroom in polypropylene film was beneficial in maintaining colour during storage for 8 days at 4°C.

pH:-

The increase in pH was observed in the mushrooms packed in different packaging materials at both ambient and refrigerated conditions as presented in Fig. 3. However, there was non-significant difference in the pH value when the effect of packaging materials on white button mushroom was taken into consideration during storage irrespective of the washing treatments. An increase in pH was recorded in mushroom treated with T_1 (plain water washing) followed by T_2 (0.5 % KMS) and T_3 (0.5 % KMS + 0.5 % NaCl + 0.5 % $CaCl_2$), irrespective of the packaging material used. Babarinde and Fabunmi (2009) also reported increase in pH of okra stored in polyethylene bag for 3 days, which implies that okra turn less acidic with increase in storage period.

Visual observation:-

A gradual decrease in firmness of packed mushrooms was observed with the advancement of storage period (Table 3 and 4) at both ambient and refrigerated conditions, which could be attributed to protein and polysaccharide degradation, hyphae shrinkage, central vacuole disruption and expansion of the intercellular space at the pileal surface (Zivanovic *et al.*, 2000). Murr and Morris (1975) reported that change in texture is delayed due to a non-perforated film as the respiration rate decreases and development is retarded. Moreover, texture loss decreases when the CO_2 concentration increases (Lopez-Briones *et al*., 1992). Loss of water content in fresh mushroom has a direct relationship of phenol oxidase activity, which could be correlated with the visual degree of mushroom browning. The degradation of colour and texture was noticed in mushrooms after 3 days of storage at ambient condition, while the mushroom at refrigerated condition was acceptable up to 9 days of storage and then started to deteriorate, which was accompanied by the fungal growth. The maximum browning was observed in mushroom packed with PPSW and minimum with PP and those packed with LDPE, after 3 days of storage at both ambient and refrigerated conditions. At ambient condition, the slight yellowing of mushrooms was noticed in all the packaging materials

accompanied by the formation of H_2S gas inside the package. Among treatments, the mushroom treated with T_3 found to be best in retarding the degradation of colour and texture when compared to T_1 (plain water washing) and T_2 (0.5% KMS). Beelman and Simon (2000) reported that mushroom treated with 0.03 % $CaCl_2$ are more resistant to the adverse effects of excessive handling or bruising owing to vacuolar integrity improvement.

Table 1:- Effect of washing treatment and packaging on moisture content (%) of white button mushroom stored at ambient condition (22±2 °C) and refrigerated condition (4+2 °C)

Treatment (T)	Packaging Material (P)	Storage Interval (D)/ Storage Condition (C)			Mean	Grand Mean (T)	Grand Mean (P)
		0 day	3days AT	3days RT			
T_1	PP	90.00	85.39	85.50	86.96	87.64	88.88
	LDPE	90.00	85.27	85.38	86.88		88.81
	CU	90.00	85.19	85.30	86.83		88.75
	PPSW	90.00	85.04	85.15	86.73		88.68
Mean		90.00	85.22	85.33			
T_2	PP	92.39	85.56	85.67	87.87	88.89	
	LDPE	92.39	85.42	85.53	87.78		
	CU	92.39	85.23	85.34	87.65		
	PPSW	92.39	85.12	85.23	87.58		
Mean		92.39	85.33	85.44			
T_3	PP	89.97	89.82	89.93	89.91	89.82	
	LDPE	89.97	89.62	89.73	89.77		
	CU	89.97	89.57	89.68	89.74		
	PPSW	89.97	89.42	89.53	89.64		
Mean		89.97	89.61	89.72			
Grand Mean (D)		90.79	86.78				
Grand Mean (C)			88.75	88.81			
CD (P= 0.01)		T= 0.84 P= NS C= NS D= 0.68 TxP= NS TxC= NS PxC= NS TxD= 1.18 PxD= NS CxD= NS TXPXC= NS TXDXP= NS TXCXD= NS PxCxD= NS TXPXCxD= NS					

T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping
AT= ambient condition, RT= refrigerated condition

Table 2:- Effect of washing treatment and packaging on total phenols (%) of white button mushroom stored at ambient condition (22±2 °C) and refrigerated condition (4+2 °C)

Treatment (T)	Packaging Material (P)	Storage Interval (D)/ Storage Condition (C)			Mean	Grand Mean (T)	Grand Mean (P)
		0 day	3days AT	3days RT			
T_1	PP	0.39	0.15	0.21	0.25	0.26	0.32
	LDPE	0.39	0.11	0.17	0.22		0.29
	CU	0.39	0.07	0.13	0.20		0.28
	PPSW	0.39	0.05	0.11	0.18		0.27
Mean		0.39	0.09	0.15			
T_2	PP	0.41	0.21	0.27	0.30	0.29	
	LDPE	0.41	0.14	0.20	0.25		
	CU	0.41	0.12	0.18	0.24		
	PPSW	0.41	0.09	0.15	0.22		
Mean		0.41	0.14	0.20			
T_3	PP	0.42	0.26	0.32	0.33	0.33	
	LDPE	0.42	0.20	0.26	0.29		
	CU	0.42	0.18	0.24	0.28		
	PPSW	0.42	0.16	0.22	0.27		

Mean		0.42	0.20	0.26			
Grand Mean (D)		0.41	0.17				
Grand Mean (C)			0.27	0.31			
CD (P= 0.01)	T= 0.04 P= 0.04 C= 0.03 D= 0.03 TxP= NS TxC= NS PxC= NS TxD= 0.05 PxD= 0.06 CxD= 0.04 TXPXC= NS TXDXP= NS TXCXD= NS PxCxD= NS TXPXCxD= NS						

T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping
AT= ambient condition, RT= refrigerated condition

Table 3:- Effect of washing treatment and packaging on visual observation of white button mushroom stored at ambient (22+2 °C)

Treatments (T)	Packaging Materials (P)	Storage Interval (D)	
		0 day	3 days
T_1	**PP**	White, firm, unblemished	Whitish brown, less firm
	LDPE	White ,firm, unblemished	Browning, less firm
	CU	White, firm, unblemished	Browning , spongy
	PPSW	White, firm, unblemished	Prominent browning, spoiled
T_2	**PP**	White, firm, unblemished	Yellowish white, firm
	LDPE	White, firm, unblemished	Yellowish brown, firm
	CU	White, firm, unblemished	Yellowish brown, slightly slimy, firm
	PPSW	White, firm, unblemished	Browning, fungal growth, spoiled and unacceptable
T_3	**PP**	White, firm, unblemished	Whitish brown, firm
	LDPE	White, firm, unblemished	Whitish yellow, firm, slightly slimy and stinky
	CU	White, firm, unblemished	Whitish yellow, browning, firm, stinky
	PPSW	White, firm, unblemished	Yellowish brown, somewhat slimy and stinky, unacceptable

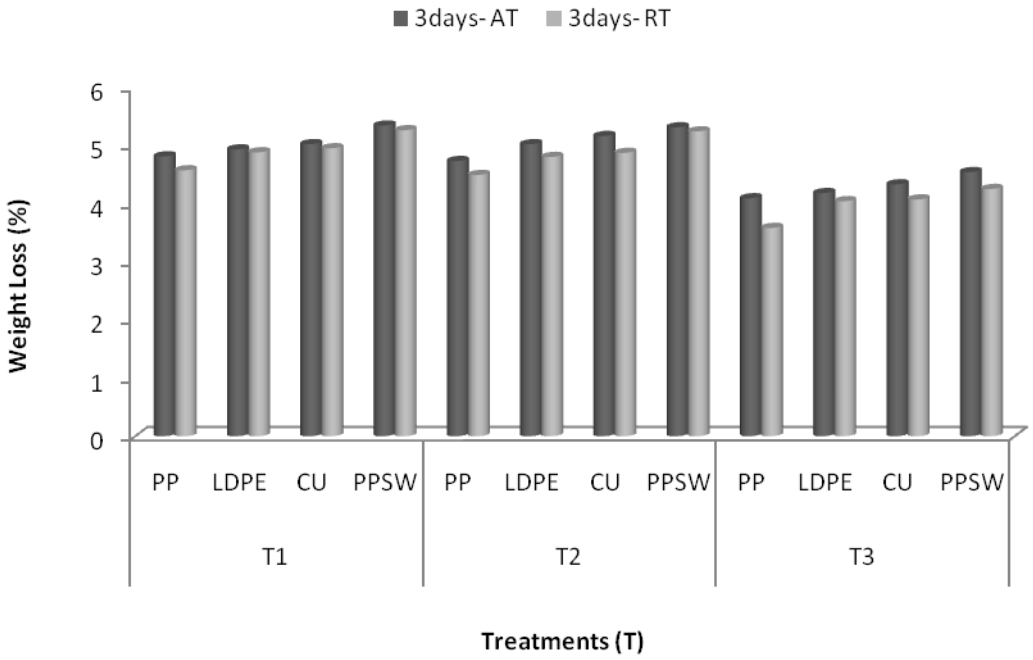
T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping

Table 4:- Effect of washing treatment and packaging on visual observation of white button mushroom stored at refrigerated condition (4+2 °C)

Treatments (T)	Packaging Materials (P)	Storage Interval (D)			
		0 day	3 days	6 days	9 days
T_1	**PP**	White, firm, unblemished	Whitish brown, firm	Whitish brown, less firm	Browning, less firm
	LDPE	White ,firm, unblemished	White, browning,	Browning, less firm	Browning, less firm
	CU	White, firm, unblemished	Browning, spoiled, fungal growth	Blackish brown, spongy	Blackish brown, spongy
	PPSW	White, firm, unblemished	Prominent browning, spoiled	Blackish brown, spongy	Spoiled, fungal growth
T_2	**PP**	White, firm, unblemished	Whitish yellow, firm	Whitish yellow, slight browning, firm	Whitish brown, less firm
	LDPE	White, firm, unblemished	Whitish yellow, slight browning, firm	Whitish brown, slight yellowing, firm	Browning, less firm
	CU	White, firm, unblemished	Whitish yellow, browning, firm	Whitish brown, slight yellowing, less firm	Browning, stinky, less firm

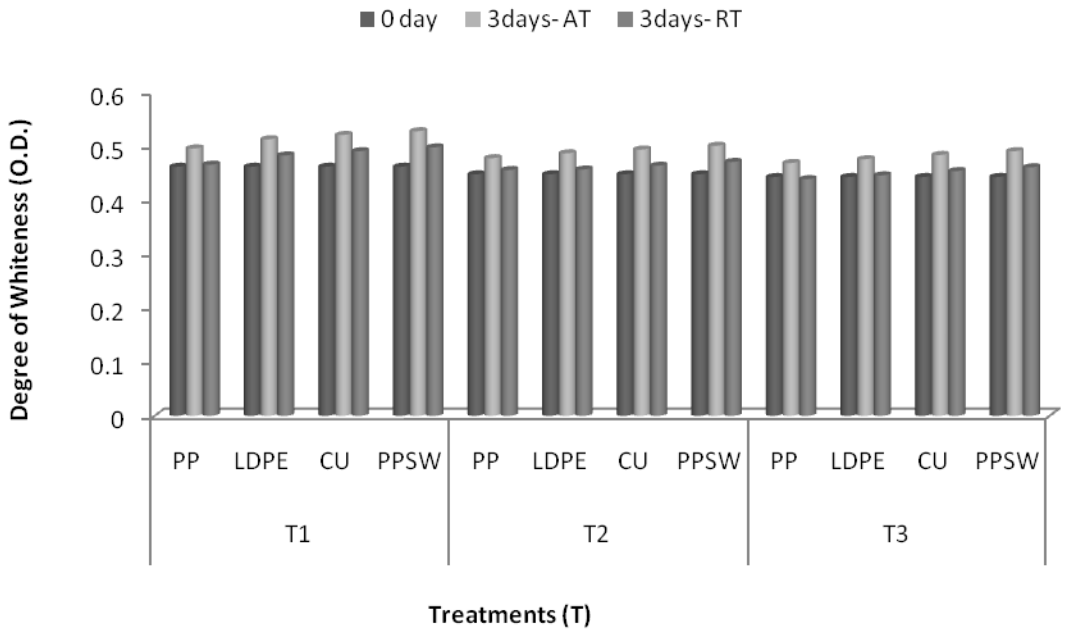
	PPSW	White, firm, unblemished	Whitish yellow, browning, less firm	Whitish brown, slight yellowing, spongy	Browning, spoiled
T_3	**PP**	White, firm, unblemished	White, initiation of browning, firm	Whitish brown, firm	Whitish brown, less firm
	LDPE	White, firm, unblemished	White, slight browning, firm	White, browning, firm	Whitish brown, less firm
	CU	White, firm, unblemished	White, slight browning, firm	White, browning, firm, stinky	Whitish brown, less firm, stinky
	PPSW	White, firm, unblemished	White, browning, slightly spongy	Browning, less firm, unacceptable	Browning, spoiled

T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping



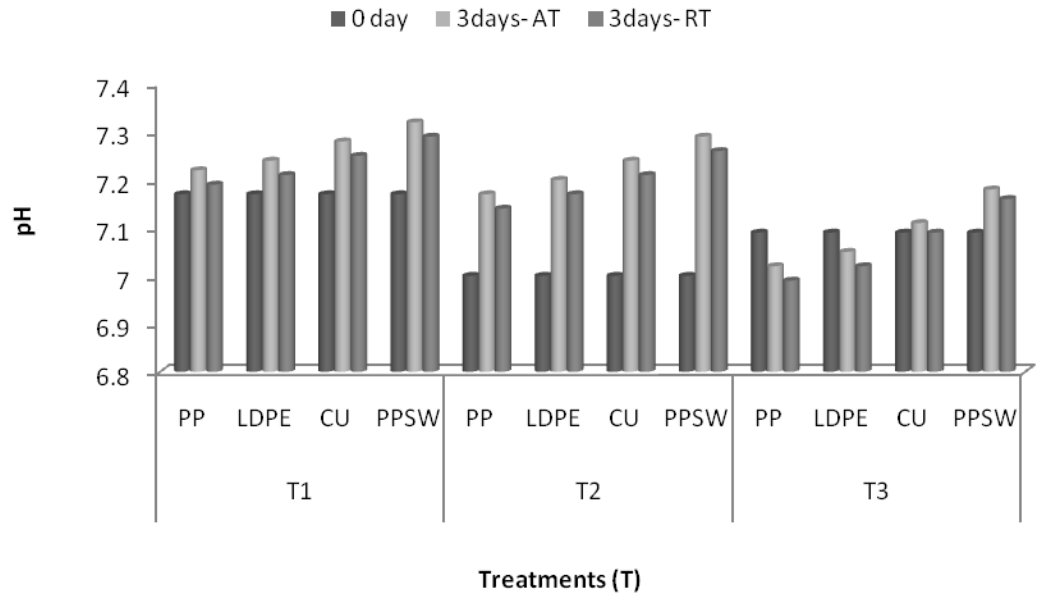
T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping
AT= ambient condition, RT= refrigerated condition

Fig. 1:- Effect of packaging on weight loss (%) by white button mushroom stored at ambient (22+2 °C) and refrigerated condition (4+2 °C)



T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping
AT= ambient condition, RT= refrigerated condition

Fig. 2:- Effect of packaging on degree of whiteness (O.D.) of white button mushroom stored at ambient (22+2 °C) and refrigerated condition (4+2 °C)



T_1= plain water washing, T_2= 0.5 % KMS, T_3= 0.5 % $CaCl_2$ + 0.5 % KMS + 0.5 % NaCl
PP= polypropylene, LDPE= low density polyethylene, CU= commercially used package, PPSW= paper punnet with shrink wrapping
AT= ambient condition, RT= refrigerated condition

Fig. 3:- Effect of packaging on pH of white button mushroom stored at ambient (22+2 °C) and refrigerated condition (4+2 °C)

Conclusions:-

From the present study it can be concluded that washing mushrooms in 0.5 % KMS + 0.5 % NaCl+ 0.5 % $CaCl_2$ solution for 2 min and packing in polypropylene increases the shelf-life of white button mushroom for 3 days at ambient condition, which was at par with the quality of fresh white button mushroom with respect to visual observation as well as on the basis of chemical evaluation. While on the basis of colour and texture the mushroom treated as above and stored at refrigerated condition was acceptable up to 6 days of storage.

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