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RESEARCH ARTICLE

OPTIMIZATION OF COATING TIME OF HYDROCOLLOID BASED EDIBLE COATING FOR SHELF LIFE EXTENSION OF LIGHT RED TOMATOES.

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Abstract

The aim of the study was to optimize the coating time of the hydrocolloid based edible coating for the light red stage tomatoes. The coating was applied onto the tomatoes by the dipping method for the different coating times varying from 0.5 to 5 min (i.e. 30 s, 1 min, 2 min, 3 min, 4 min and 5 min) and various responses like gas concentration, physiological weight loss (PL_w) of tomatoes, coating thickness and coating pick up were studied. The tomatoes coated for 4 min were found to have the least PL_w (3.43%) and minimum change in gas concentration with 1.1% carbon dioxide (CO_2) and 19.4% oxygen (O_2), whereas control sample registered higher values of moisture loss ($9.42 \pm 1.84\%$) and 3.5% CO_2 and 14.9% O_2 after 5 days of storage at 10 °C and 85% relative humidity. The coating pickup for the tomatoes coated for 4 min was of 4.9 ± 0.3 and coating thickness 12.5 ± 0.87 micron. The treatment was found to have a significant reduction in moisture loss and respiration rate at 5% significant level effect on the responses studied.

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Introduction:-

Tomato is globally the second most important vegetable crop after the potato. With an annual production of 18.2 MT during the year 2013, India ranks 2nd after China, contributing around 11% in the total world production (163 MT) of tomato (FAOSTAT, 2013). Tomato is a major contributor of carotenoids (especially lycopene), phenolics, vitamin C and small amounts of vitamin E in daily diets (Pila et al., 2010). In order to prolong their availability in the market throughout the year, the perishable commodities like tomato (Mojevic and Tesanovic, 2011; Tosati et al., 2015) need to be handled and stored with due care. Certain postharvest constraints, including short shelf life due to respiration, moisture loss, ripening and susceptibility to diseases limit their long duration storage and transportation. Tomatoes being a climacteric fruit, the start of ripening is accomplished by a rapid rise in respiration rate called “respiratory climacteric” during which oxidative breakdown of complex substrates occurs, followed by ageing, leading to product deterioration (Babu et al., 2014; Srividya et al., 2014). Also tomatoes being fleshy fruits, continue to lose water after harvest. This results in a wilted, dull appearance that reduces the eye appeal and freshness and eventually becomes unmarketable.

The edible coatings is a tool that provides control of moisture loss, retardation of senescence and browning in cut produce, reduction in respiration rate and can ultimately prolong the shelf life. Therefore, the edible coating is a technology that can address all the issues associated with the spoilage of tomatoes, and can potentially extend their shelf life. Edible coating is defined as an edible material (protein, polysaccharide or lipid) that is used as a thin layer on the surface of foods (Gonzalez-Aguilar et al., 2010). It can be applied for, providing a selective barrier to oxygen, carbon dioxide and moisture, preserving fresh-cut vegetables and fruits, improving textural and mechanical properties, preventing flavor loss and carrying food additives (Tapia et al., 2008).

The edible coatings act as immediate packaging as they form a layer directly over the surface of the food material forming a film over it and limiting the gas exchanges at the cellular and surface level. As it is a sort of immediate

packaging, and there is very little space between the food surface and the film, the equilibrium conditions can be attained quickly. But for an effective edible coating, there are various factors that need to be considered such as coating time, coating concentration, conditions of coatings (like temperature). The coating time is a crucial parameter, as it decides the thickness of coating, which can greatly affect the major parameters affecting shelf life of fresh produce such as respiration rate, moisture loss, firmness etc. The other parameters (coating concentration and temperature) have been studied and are a part of a separate study. The present study includes the optimization of coating time for a hydrocolloid based edible coating (by dipping method) for the shelf life extension of light red stage tomatoes. The effect of coating time on the physiological weight loss of tomatoes, change in package concentration, coating pickup and thickness of the edible coating was studied.

Materials and methods:-

Fresh tomatoes were purchased from the local market of Indian Institute of Technology Kharagpur, India. The fruits with uniform size, shape, color and external appearance and also free from fungal infection were taken for the experiment. Samples were washed using chlorinated water (200 ppm) for 2 min and then left to dry at room temperature for about 1 hour. Tomatoes were chosen randomly for the application of coating on it, for each experiment 5 tomatoes were taken, 10 for the study of coated sample and 10 for control study.

Preparations of Edible Coating:-

Food-grade hydrocolloid based materials were purchased from sigma Aldrich and preparation of coating has been done according to the Tapia et al., (2008) with minor modifications. Briefly, the coating solution was prepared by mixing the components of the coating in the Millipore water and with continuous stirring on a magnetic stirrer. The coating solution was then heated at a controlled temperature of 70 °C in a water bath for 30 min, until the mixture became clear. Then, the prepared coating was homogenized within IKA Ultra Turrax T18 basic (IKAs WERKE, Germany) with a S18N-10G probe, for 5 min at 24000 rpm to form emulsions, and degassed under vacuum at 80 mbar. Once prepared, film-forming solutions/emulsions were used for coating the tomatoes.

The tomatoes were randomly chosen for the different treatments, and dipped into the prepared coating solution for different times ranging from 30 s to 5 min i.e. 30 s, 1 min, 2 min, 3 min, 4 min and 5 min at room temperature and then excess coating materials were allowed to drip off. After dipping in the coating solutions, the tomatoes were dried at ambient conditions and a fan generating low speed air was used to hasten the drying. Ten tomatoes were used for each treatment and for each study (physiological weight loss, coating pickup, respiration rate and coating thickness) and control samples (10 in no.) without any coating were also kept for comparison with the coated tomatoes.

Physiological weight loss:-

For determining the physiological loss (PL_w) in weight, fruits were weighed before imposing the treatment which served as the initial fruit weight. The coating was applied to tomatoes for different duration of times ranging from 30 s to 5 min i.e. 30 s, 1 min, 2 min, 3 min, 4 min and 5 min. The coated tomatoes were kept in open at normal ambient conditions and loss in weight of the tomatoes was recorded on each day for the 5 days and the difference was calculated as the percent weight loss as given by the following equation:

$$PL_w = \frac{W_i - W_f}{W_i} \times 100$$

Where, W_i is the initial weight of tomatoes before coating, W_f is the final weight of tomatoes and PL_w is the physiological weight loss or moisture loss of tomatoes.

Coating pickup:-

Coating pick-up was determined by the difference in weight of tomatoes before and after the coating process. The coated fruit was consistently dried under forced-air of a table fan for 5 minutes before weight measurement. The procedure for measurement of coating pick-up has been described by previous study (Hsia et al., 1992; Maskat et al., 2005; Zahid et al., 2011) with minor modifications. Briefly, the weighed amount of coating solution was taken in a beaker which was tared before putting the coating solution and the tomatoes (around 0.5 kg) which were weighed individually before adding into the coating. The tomatoes were dipped into the coating solution for 30 s, 1 min, 2 min, 3 min, 4 min and 5 min. The tomatoes coated for the different times were taken out and the excess coating was allowed to drip for 2 min into the coating solution. The weight of the coating solution was measured at the end of

each dipping + dripping time (time for which coating was allowed to drip into the coating solution). The coating pickup was calculated by the difference in the weight of coating solution (initial weight minus final weight).

Gas concentration in the package:-

The coated tomatoes with the different coating times were put into the glass containers and sealed airtight by using the closed system respirometer method (respiration rate measurement method) as described by Bhande and Goswami, 2008. The containers were stored at 10 °C and 85% relative humidity in thermostatically controlled environmental test chambers. Gas composition of respirometer was analyzed at regular period of one day interval till 5 days. Headspace gas sample was taken with the help of sampling needle, which was inserted through a silicon disc into the respirometer and analyzed quantitatively for O₂ and CO₂ concentrations using a headspace O₂/ CO₂ gas analyzer (Systech Illinois, 6600). In the headspace analyzer, a zirconium sensor is used for O₂ determination and an infrared detector is used to detect CO₂. All measurements were taken in triplicate.

Thickness:-

The uncoated fresh tomatoes were taken and a very thin section of tomato skin was peeled off. All the possible pulp was scraped out from the skin and attempt was made to make the thickness of the tomato skin uniform. The thickness of the tomato skin was measured at random positions. The section of tomato skin was dipped into the coating solution for different time duration and allowed to dry. After the coating is dried, the thickness of skin was measured again and the difference in thickness was divided by two, as in this case, the peel is getting coated from two sides unlike the whole tomatoes that will be coated only on the surface.

Results and Discussion:-

Physiological weight loss (PL_w):-

Weight loss in fruits and vegetables can be attributed to water loss because other components like gaseous products of respiration, aroma or flavor are practically undetectable in terms of weight (Olivas and Barbosa-Canovas, 2005). The cumulated physiological weight loss of coated tomatoes was studied up to days of storage at room temperature and it varied significantly ($p < 0.1$) with change in duration of the coating time. The control tomatoes, that is, the uncoated tomatoes showed the highest weight loss over the duration of five days ranging from $2.64 \pm 0.45\%$ to 9.42 ± 1.84 on day 1 and day 5, respectively. The weight loss data of uncoated tomatoes was similar to that of reported in the literature (Bhattarai and Gautam, 2006; Moneruzzaman et al., 2009). Also the PL_w decreased with the increase in coating time, which can be attributed to the fact that the edible coatings have the potential to reduce moisture loss (Azaraksh et al., 2012). However, the weight loss was found to increase at 5 min of coating duration (Fig. 1), and this trend was found on each day of storage. The hydrophilic nature of coating material could be responsible for this effect. The similar trend was reported by Azaraksh et al. (2012). The tomatoes coated for 4 min showed a minimum weight loss as compared to the other durations as shown in Table 1.

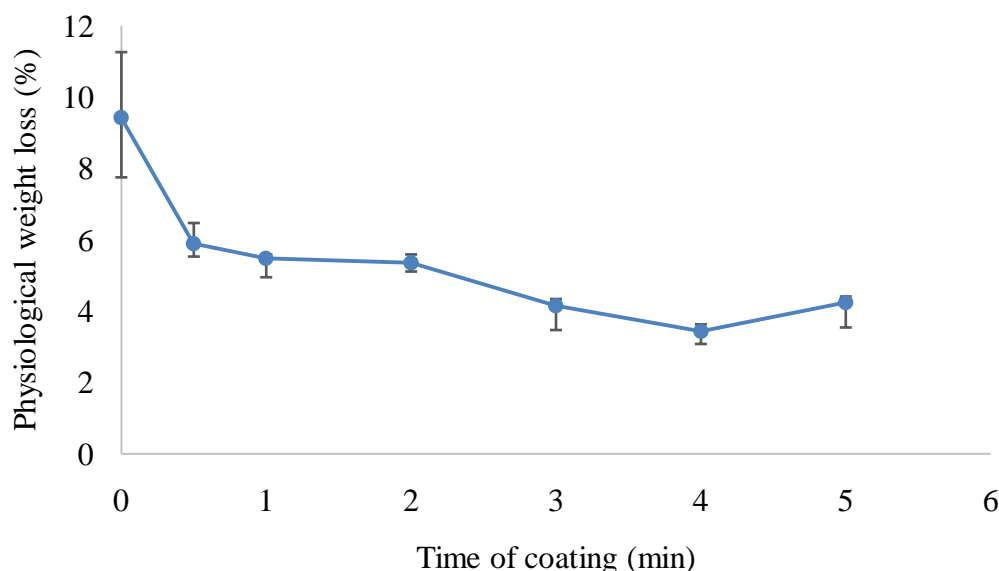


Figure 1:- Physiological weight loss of tomatoes coated with edible coating for different coating time after 5 days of storage at room temperature.

Table 1:- Physiological weight loss during storage of tomatoes coated with edible coating for different coating time

Time of coating (min)	Weight loss of tomatoes (%) during storage at room temperature till five days				
	1	2	3	4	5
0	2.64 ± 0.45	4.02 ± 1.23	5.7 ± 0.36	8.6 ± 1.67	9.42 ± 1.84
30	0.225 ± 0.005	1.73 ± 0.85	3.23 ± 0.46	4.66 ± 0.36	5.89 ± 0.58
1	0.218 ± 0.071	1.59 ± 0.32	2.96 ± 0.15	4.36 ± 0.52	5.47 ± 0.12
2	0.215 ± 0.008	1.56 ± 0.49	2.91 ± 0.27	4.27 ± 0.24	5.35 ± 0.24
3	0.212 ± 0.025	1.45 ± 0.36	2.76 ± 0.31	3.92 ± 0.68	4.15 ± 0.19
4	0.167 ± 0.032	1.15 ± 0.21	2.16 ± 0.11	3.21 ± 0.54	3.43 ± 0.11
5	0.204 ± 0.033	1.51 ± 0.38	2.84 ± 0.21	3.89 ± 0.69	4.24 ± 0.17

Coating pickup:-

The coating time significantly affected ($p < 0.05$) the amount of coating used for coating of tomatoes. All the sample means from different coating durations were found significantly different, except for the 0.5 and 1 min coating duration which did not show any significant difference as represented by the mean comparison plot of Tukey's test in Fig. 2. The amount of coating pickup varied from $0.21 \pm 0.015\%$ to $0.56 \pm 0.03\%$ for 0.5 min and 5 min, respectively. The amount of coating pickup was calculated for 1 kg of tomatoes, 5.6 g of edible coating sufficient to coat 1 kg of tomatoes. The results for amount coating pickup for different durations of coating time are presented in Table 2.

Table 2:- Coating pickup of edible coating for different durations of coating time.

Time of coating (min)	Coating pickup (g)	Weight of tomatoes	Coating pickup (%)	Coating pickup in g per kg of tomatoes
0.5	1.02 ± 0.015	485.71 ± 4.04	0.21 ± 0.015	2.1 ± 0.1
1	1.085 ± 0.014	474.26 ± 4.35	0.228 ± 0.019	2.28 ± 0.3
2	1.778 ± 0.055	490.03 ± 3.87	0.362 ± 0.012	3.62 ± 0.08
3	1.913 ± 0.061	497.26 ± 4.89	0.384 ± 0.023	3.84 ± 0.5
4	2.429 ± 0.15	495.52 ± 5.41	0.49 ± 0.09	4.9 ± 0.3
5	2.85 ± 0.09	508.33 ± 6.03	0.56 ± 0.03	5.6 ± 0.7

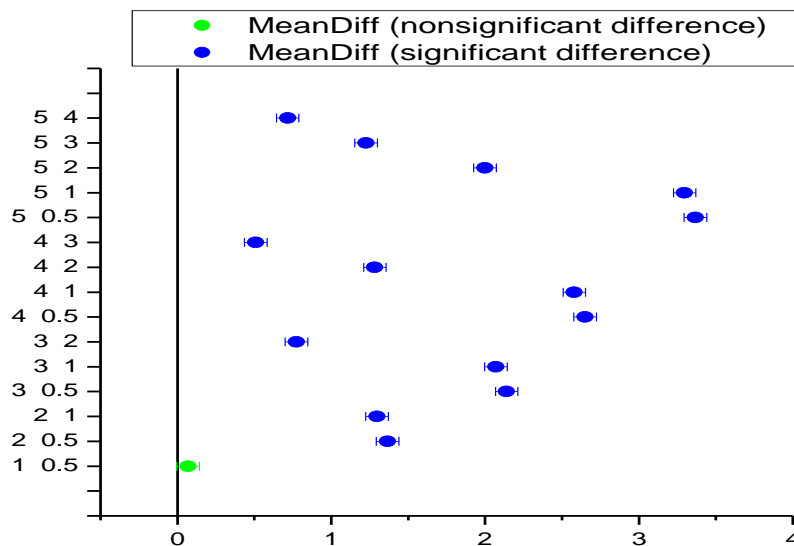
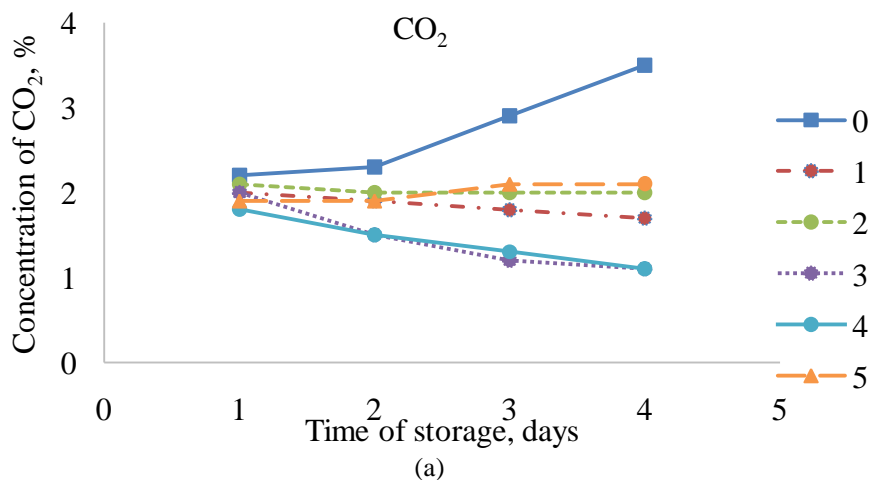


Figure 2:-Mean comparison plot of Tukey's test for different times of coating duration.

Gas concentration:-

The edible coatings are said to have potential for the reduction of respiration rate of fresh fruits and vegetables (Olivas and Barbosa-Canovas, 2005). This effect can be associated with the reduction in metabolic activities such as respiration rate and decrease in concentration of oxygen (O_2) and increase in carbon dioxide (CO_2) concentration (Olivas and Barbosa-Canovas, 2005; Gonzalez-Aguilar et al., 2010). The edible coatings as immediate packaging that is formed directly over the surface of the food product. Therefore, by forming a film over the surface, it limits the gas exchanges at the cellular and surface level. It has the selective permeation for oxygen and carbon dioxide, which may slow down the interchange of CO_2 and O_2 between the environment and the coated fruit (Gonzalez-Aguilar et al., 2010). This effect was evident in the present study also, where the uncoated tomato fruits showed the maximum change in concentration of O_2 and CO_2 with the 3.5% CO_2 and 14.9% O_2 after 4 days of storage 10 °C and 85% relative humidity. The coated tomatoes showed varied rates of change in concentration of gases over the period of storage. The tomatoes coated with the duration time of 3 min (1.1% CO_2 and 19.3% O_2) and 4 min (1.1% CO_2 and 19.4% O_2) showed almost the equal change in concentrating of gases after 4 days of storage at 10 °C and 85% relative humidity (Fig.3 (a) and (b)).



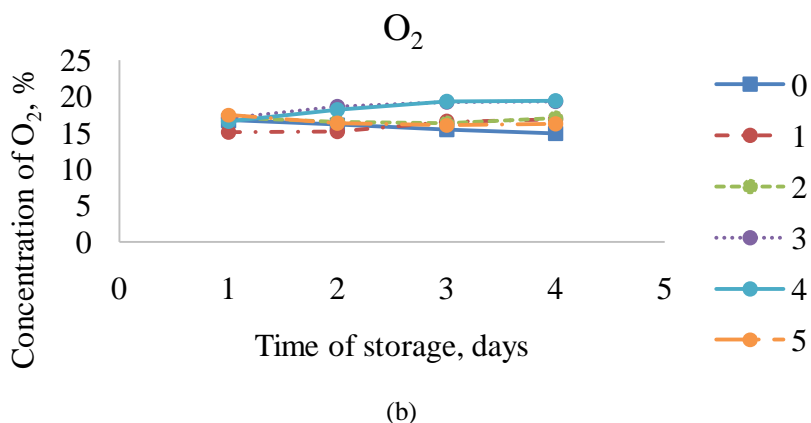


Figure 3:- Change in gas (a) CO₂ and (b) O₂ concentration of tomatoes stored in a closed system respirometer with the different duration of coating time.

Coating Thickness:-

The thickness of coating is an important parameter as it largely affects the functionality of coatings, typically the permeability in terms of O₂, CO₂ and water vapor transmission rate. Thickness of the coating did not vary significantly ($p < 0.5$), however, an increase in coating thickness was noted with increase in dipping time of tomato peel. The coating was found to be 8.3 ± 0.94 , 10.5 ± 0.76 , 12.5 ± 0.87 , 14 ± 0.81 micron for 2, 3, 4 and 5 min of coating duration, respectively. The thickness, however, of the coating could not be determined for 0.5 and 1 min duration of dipping time because of very slight differences. Coatings exceeding a critical thickness can cause detrimental effects of reduced internal O₂ concentration and increasing CO₂ concentration from anaerobic fermentation (Lin and Zhao, 2007). The thickness of coating varies with density, viscosity, surface tension, and draining time of the biopolymer solution (Cisneros-Zevallos and Krochta, 2003).

Conclusion:-

The tomatoes coated for 3 min and 4 min showed the minimum change in gas concentration i.e. 1.1% CO₂ and 19.3% O₂ for 3 min and 1.1% CO₂ and 19.4% O₂ for 4 min coating duration. However, the tomatoes coated for 4 min showed the least amount of physiological weight loss (3.43%). The best conditions for the optimization of duration of dipping time can be found by balancing changes in gas concentration and weight loss, as both of these parameters are crucial and can greatly affect the shelf life of fresh produce. Therefore, the optimized duration can be selected as 4 min, which uses 4.9 ± 0.3 g of edible coating for one kg of tomatoes with the coating thickness of 12.5 ± 0.87 micron.

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