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Gum arabic based composite edible coating on green chillies

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A b s t r a c t. Green chillies were coated with a composite edible coating composed of gum arabic (5%), glycerol (1%), thyme oil (0.5%) and tween 80 (0.05%) to preserve the freshness and quality of green chillies and thus reduce the cost of preservation. In the present work, the chillies were coated with the composite edible coating using the dipping method with three dipping times (1, 3 and 5 min). The physicochemical parameters of the coated and control chillies stored at room temperature (28±2ºC) were evaluated at regular intervals of storage. There was a significant difference ($p \leq 0.05$) in the physicochemical properties between the control chillies and coated chillies with 1, 3 and 5 min dipping times. The coated green chillies showed significantly ($p \leq 0.05$) lower weight loss, phenolic acid production, capsaicin production and significantly ($p \leq 0.05$) higher retention of ascorbic acid, total chlorophyll content, colour, firmness and better organoleptic properties. The composite edible coating of gum arabic and thyme oil with 3 min dipping was effective in preserving the desirable physico-chemical and organoleptic properties of the green chillies up to 12 days, compared to the uncoated chillies that had a shelf life of 6 days at room temperature.

K e y w o r d s: chilli, edible, gum arabic, preserving, shelf- life

INTRODUCTION

Horticultural products are highly vulnerable. During the post-harvest, there is massive damage due to microbes, insects, respiration and transpiration (Raghav *et al.*, 2016). The important excellence factors of fresh product that influence marketability consist of colour, texture, appearance, flavour, nutritional quality and microbial safety. These quality parameters are evaluated by plant variety, ripening stage, maturity stage, pre-harvest and post-harvest conditions (Lin and Zhao, 2007). The various criteria of appearance consist of colour, consistent size and measurement, wilting, skin wrinkling, loss of surface gloss and skin blemishes formed by natural senescence or the growth of microorganisms (Lin and Zhao, 2007). The firmness and colour are varied as a result of the increased activity of naturally present biocatalysts such as chlorophyllase, pectinase, cellulases, esterases, polyphenol oxidases (PPO) and peroxidases (Zhang *et al.*, 2004). Chilli is considered as being one of the most vital cash crops and is an extensively used universal spice. India contributes to 36% (around 14 lakh tonnes) of the overall world's chilli production (Karpate and Saxena, 2009). Indeed, India leads in export, by a 25% (2.09 lakh t) share in world trade, and India shipped 16.4% of its total chilli production in 2007-2008. The export of chilli contributes to 48% with respect to quantity and 28% with respect to the value of the total export of spices from India (Karpate and Saxena, 2009). Chilli holds a high moisture content (60-85%) during the moment of the harvest. This makes it liable to microbial attack, so the chillies are usually dried. Major losses are due to moisture (15-25%), spoilage in the field (1-10%), farm to assembling (5-10%) and assembling to distribution (2-5%) (Karpate and Saxena, 2009). Since the farm level storage is not adequate in India, a practical, less costly technology would encourage more farmers to stock chillies. Fresh chillies contains 111.0 mg vitamin C per 74 g when compared to oranges that contain 37 mg. Such a situation makes them very competent healing agents for cellular damage and immune system stimulants. Chillies also provide favourable effects on the circulatory system. Their consumption prevents the buildup of cholesterol and reduces platelet gathering, hence minimises the threat of myocardial infarction (Karpate and Saxena, 2009). Even

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if there are many methods to extend the post-harvest storage life of chillies, edible coating proves to be one of the least expensive options, especially in a developing country like India, where energy reserves are limited. The edible coating is the slender layer of consumable material that can offer a limitation to oxygen, microbes of an external source, moisture and solute migration for food. It imparts a semi--permeable barrier that enhances the shelf life by lessening moisture and oxidative reaction rates, solute migration, gas exchange and respiration, and also minimises physiological disorders on fresh cut fruits (Park, 1999). An edible coating must make sure the constancy of food and prolong its shelf life. Gum arabic (GA) is a reasonably acidic salt of a compound polysaccharide that contains calcium, magnesium and potassium ions (Prakash *et al*., 1990). It is collected from the branches of acacia species and is normally used in the food manufacturing sector as a food additive (Motlagh *et al.*, 2006). The gum collected from *Acacia senegal* is the principal gum used for commercial purposes because it has enhanced emulsification properties when correlated to the gum collected from *Acacia seyal* (Elmanan *et al*., 2008). It is been allowable as an unthreatened compound by the joint FAO/WHO Expert Committee on Food Additive (Anderson and Eastwood, 1987). Gum Arabic is a primary coating component owing to its emulsifying properties, and adding either lemon grass or cinnamon oil into Gum Arabic was found to retard *Colletotrichum musae* in bananas (Maqbool *et al*., 2011). Gum arabic also showed positive results and significantly delayed ripening of cold--stored apples (El-Anay *et al*., 2009). *T. vulgaris* L. is a herbaceous plant that is most often woody. The antifungal character of thymol is due to thymol's ability to transform the hyphal morphology and making hyphal aggregates, yielding abridged hyphal diameters and lysis of the hyphal wall (Numpaque *et al*., 2011). Additionally, thymol is hydrophobic, facilitating it to intermingle with the cell membrane of fungus cells, altering cell membrane permeability by letting the loss of macromolecules (Segvic *et al*., 2007). Oil of thyme, the essential oil of common thyme (*T. vulgaris* L.), contains 20 to 54% thymol. The essential oil obtained from thyme is also a rich source of p-cymene, borneol and linalool. Thyme oil was found to inhibit the growth of *C. gloeosporiodes* invitro or invivo in avocado cultivars Hass and Fuerte (Sellamuthu *et al*., 2013). The addition of thyme oil in the vapour phase in the modified atmosphere was found to enhance the activities of defence enzymes such as chitinase, peroxidase, PAL and 1,3-ß glucanase, as well as antioxidant enzymes such as catalase and superoxide dismutase (Sellamuthu *et al*., 2013). The objective of this work was to study the impact of the composite edible coating of gum arabic and thyme essential oil in extending the shelf life of green chillies stored at room temperature.

MATERIALS AND METHODS

Green chillies of the same dimension, colour and maturity were bought from the local market, Potheri, Chennai, India. Gum arabic was procured from SRL Pvt Ltd, Chennai, India. Glycerol and tween 80 was purchased from SRL Pvt Ltd, Chennai, India. Thyme oil was bought from Synthite Industries Ltd, Kerala, India. Standard Capsaicin of 95% purity were purchased from Sigma-Aldrich. Standard ascorbic acid and standard gallic acid were purchased from SRL Pvt Ltd, Chennai, India. Gum arabic solution (5%) was made by dissolving 5 g of gum arabic powder in 100 ml purified water. The solution was stirred in low heat (40ºC) for 60 min on a hot plate magnetic stirrer and then filtered using cheese cloth to remove any undissolved impurities (Ali *et al*., 2010). After cooling to 20ºC, glycerol monostearate (1.0%) was incorporated as a plasticiser to improve the potency and flexibility of the coating solutions. The pH of the coating solution was adjusted to 5.6 with 1N NaOH. Then, tween 80 (0.05%) was added as surfactant followed by thyme oil (0.5%). This solution was homogenised at 13 500 r.p.m. for 10 min in an Ultraturrax homogeniser. The Viscosity of the coating solutions was checked by the viscometer (Brookfield viscometer DV-II +pro). Green chillies were washed using sodium hypochlorite (0.05%) for 2 min and air-dried at ambient temperature. After drying, the green chillies were randomly separated for different treatments and each treatment was conducted with three replicates. The green chillies were dipped in gum arabic coating solutions (5%) coating solution for 1, 3 and 5 min and it was made sure that the coating solution was spread uniformly on the whole surface while control chillies were dipped in the distilled water. The chillies were then air-dried and stored at room temperature (28±2ºC). The data was collected before treatment (*i.e.* day 0) and in every 48 h for 12 days. All the analysis was performed in triplicate. The weight loss in control and the coated chillies samples was calculated using the following formula (Qayyum *et al*., 2014):

$$\textit{Weight loss}\ (\%) = \frac{\textit{initial weight - final weight}}{\textit{initial weight}}\ 100.$$

For the determination of total soluble solids (T.S.S.), 10 g of fruit was crushed in a blender and juice was filtered through a muslin cloth. T.S.S. of the filtrate were determined by hand refractometer (Chaple *et al*., 2016).

For the measurement of pH, 10 g of chilli were smashed in a blender and 90 ml of deionised water was added. It was subsequently filtered through the cheese cloth and the pH value of the solution was monitored with a pH meter (Antoniali *et al*., 2007).

In order to estimate the total chlorophyll content, the chillies were finely ground in a mortar pestle to a paste with 20 ml of 80% acetone. The slurry was centrifuged at 5 000 r.p.m. for 5 min and the supernatant was taken to

100 ml volumetric flask, while residue was again extracted in 20 ml of 80% acetone and the supernatant was transferred to the same volumetric flask. The above procedure was performed again and again until the residue was colourless. The supernatant collected was made up to 100 ml using 80% acetone and absorbance was recorded at 645 and 663 nm (Chaple *et al.*, 2016).

The UV-Visible spectrophotometer method using 2, 6 dichlorophenol indophenols was employed for the estimation of the ascorbic acid of the coated and control chillies. The ascorbic acid content was determined at 520 nm (Ranganna, 1999).

For the estimation of total phenolic content, approximately 2 g of ground chilli sample was extracted in 20 ml of 90% methanol for 2 h. It was then filtered and total phenolic content was estimated with gallic acid as a standard (Chaple *et al.*, 2016).

The firmness of both control and the coated chillies were analysed throughout the storage period by using the TA-XT Plus digital texture analyser (Chaple *et al.*, 2016). The penetration test was used to find out the firmness of chillies. A cylindrical probe of 2 mm diameter was allowed to penetrate through the chillies up to 6 mm depth. During the test, the load cell of 50 kg, pretest speed of 1.5 mm s^{-1}, the test speed of 1.0 mm s^{-1} and post-test speed of 10 mm s^{-1} were used. The force that is essential to break through the chilli skin was evaluated in terms of Newton.

The L*, a* and b* values of the chilli peel were analysed using the Hunter Color Quest XE analyser. The L* values depict the lightness, a* value represents the intensity of the redness or greenness, and b* values show the degree of blueness or yellowness (Ranganna, 1986).

For the determination of capsaicinoids, the coated and control chillies were oven-dried at 60ºC for 5 days, grounded to a fine powder and stored in sealed plastic bags at 20ºC until processed. Capsaicinoids were extracted using the soxhlet extraction method, employing ethanol solvent at 50ºC, followed by its evaporation.

A stock solution of capsaicin was made by mixing 2 mg of standard capsaicin in 2 ml of methanol. Working solutions were made by diluting the stock solution to the desired concentration with methanol.

For running the HPLC, acetonitrile and water were taken in the ratio 50:50 (vol:vol). The temperature of the Betasil C 18 column was maintained at 60ºC during the chromatographic separation. The flow rate was 1.5 ml min^{-1}, and the chromatography was run for 10 min (Tilahun *et al.*, 2013). The eluting compounds were monitored at a wavelength of 222 nm. The sample solution or standard capsaicin solution (5 µl) was directly introduced into the HPLC apparatus using a hypodermic syringe. A retention time of 6.596 min was obtained for standard capsaicin.

The peel of control chilli and chillies coated for 1, 3 and 5 min dipping time was subjected to SEM analysis after freeze drying to infer the microstructure of the coating on the fruits (Athmaselvi *et al.*, 2013).

A photographic camera (16 Mpix. Cyber-shot, Sony) was used to monitor the changes in the appearance of the green chillies (Ochoa-Reyes, 2013).

The sensory examination of the chillies was performed on the final day of storage, to infer the consequence of coating on the sensory traits of the chillies. The scoring was done by 20 panellists of the 21-25 age group. The sensory characteristics such as firmness, appearance, colour, smell, and overall acceptability were considered so as to learn the effect of coating on the sensory attributes of green chillies (Menezes and Athmaselvi, 2016). A 9-point hedonic scale on which 9 implies excellent and 1 represents unacceptable, was used in analysing the control and the coated green chillies to find their sensory quality.

In order to check the impact of coating on the sensory traits of green chillies when it is cooked, two sets of spicy dip chutney were prepared using the same quantity of coated and control green chillies, respectively, along with an equivalent quantity of tomato, onion, salt and some water. It was the served with bread sticks. The sensory assessment was conducted by 20 panellists of the 21-25 age group who scored the samples using the 9 points hedonic scale. Sensory traits such as taste, flavour, colour, smell and overall acceptability were employed to study the outcome of the composite coating on the sensory attributes of the cooked green chillies.

The ANOVA test ($p \leq 0.05$) was conducted for the statistical analysis of the data using the SPSS software (version 20). Tukeys test was used for the evaluation of difference between means.

RESULTS AND DISCUSSION

The viscosity (cP, at 28ºC) of the coating solution was observed to be 17.1±0.24. An increase in the weight loss was noted in the case of both the control and coated green chillies during its storage at room temperature. The uncoated green chillies exhibited an enhancement in the weight loss from 2.642±0.15 to 14.536±0.48%, whereas with the green chillies dipped for 1, 3 and 5 min, the weight loss increased from 0.892±0.27 to 7.027±0.35%, 0.224±0.22 to 6.247±0.41% and 0.545±0.34 to 6.757±0.47%, respectively, from the 2nd to the 12th day of storage. There was a significant variation ($p \leq 0.05$) in the weight loss between the uncoated chillies and chillies dipped for 1, 3 and 5 min, respectively. This may be due to the composite edible coating retarding the transpiration rate, resulting in reduced water loss, hence, reduced weight loss. Dipping green chillies in the composite edible coating for 3 min was effective in preserving the freshness till the end of the 12th day of storage (Table 1). There was comparatively more weight

Table 1. Weight loss and T.S.S. values of control and coated green chillies

Day	Control	Coated			Control	Coated		
		1 min	3 min	5 min		1 min	3 min	5 min
	Weight loss (%)				T.S.S. (º Brix)			
2	2.642±0.15a	0.892±0.27b	0.224±0.22c	0.545±0.34d	7.5±0.04a	7.1±0.07b	7.0±0.13b	7.1±0.24b
4	4.724±0.26a	1.214±0.42b	1.047±0.16c	1.097±0.38c	7.8±0.17a	7.1±0.08b	7.0±0.02b	7.1±0.15b
6	7.495±0.21a	3.857±0.36b	3.026±0.28c	3.425±0.53d	8.3±0.19a	7.2±0.09b	7.0±0.05b	7.1±0.14b
8	8.748±0.18a	5.026±0.27b	4.326±0.36c	4.875±0.44d	8.8±0.15a	7.5±0.06b	7.1±0.12b	7.3±0.11b
10	11.529±0.25a	6.425±0.28b	5.874±0.52c	6.029±0.35d	8.6±0.06a	7.7±0.09b	7.3±0.16b	7.5±0.05b
12	14.536±0.48a	7.027±0.35b	6.247±0.41c	6.757±0.47d	8.3±0.17a	7.8±0.13b	7.4±0.07b	7.6±0.07b

Data is expressed as mean±SD, n=3. Means in each row followed by the different letters are significantly different ($p \le 0.05$) by Tukey test.

loss for 5 min coated green chillies than 3 min coated green chillies since the increased thickness of coating resulted in anaerobic respiration. Interrelated results were reported by Chitravathi *et al.* (2014) with a shellac-based edible coating when coated on green chillies.

There was an increase in the T.S.S. value of both uncoated and coated green chillies throughout storage at ambient storage conditions. Coated samples exhibited no rise in T.S.S. till day 6 of storage (Table 1). A steady and slow rise was seen in T.S.S. for coated samples, reaching a peak on the 12th day of storage, whereas the control samples exhibited the highest T.S.S. content on day 6. The probable cause for the rise in T.S.S. in uncoated chillies could be the disintegration of the complex sugars such as starch, to simple sugars, during storage. In uncoated samples, gain in T.S.S. can also result due to moisture loss by the fruit and transformation of organic acids to sugars (Chaple *et al*., 2016). Further reduction in T.S.S. could be attributed to the commencement of senescence. The T.S.S. was found to increase during storage of five hot peppers cultivated in Ethiopia (Samira *et al*., 2013). The T.S.S. value of control chilli samples changed from 7.5±0.04 to 8.3±0.17ºBrix and in the case of the green chillies dipped in the composite coating for 1, 3 and 5 min, the T.S.S. value ranged from 7.1±0.07 to 7.8±0.13ºBrix, 7.0±0.13 to 7.4±0.07ºBrix and 7.1±0.24 to 7.6±0.07ºBrix, respectively, from the 2nd to the 12th day of storage, as shown in Table 1. There was a significant ($p \le 0.05$) variation in the T.S.S. of control chillies and chillies coated for 1, 3 and 5 min.

The pH of the composite edible coating was observed to be 5.62±0.34, thus the pH of the coated sample did not get affected by the pH of composite coating. The carbohydrate and acid metabolism are linked with a post-harvest ripening period that may result in deviation in the pH of the produce (Padmaja *et al*., 2015). The pH value of control chillies ranged from 5.68±0.22 to 5.98±0.36, and that of chillies dipped for 1, 3 and 5 min varied from 5.62±0.53 to 5.84±0.33, 5.59±0.46 to 5.70±0.25 and 5.61±0.14 to 5.78±0.22, respectively, from the 2nd to the 12th day of storage. There was a significant difference ($p \le 0.05$) in pH values between uncoated and coated fruits of all the three dipping times (Table 2).

Total chlorophyll content of coated chilli samples persisted with comparatively minimal variation implying a beneficial effect of coating on decelerating the ripening process. The total chlorophyll content of control chilli samples changed from 40.52±0.36 to 14.46±0.32 mg 100 g^{-1}, and in the case of the green chillies dipped in the composite coating for 1, 3 and 5 min, the total chlorophyll content ranged from 43.24±0.51 to 32.25±0.44 mg 100 g^{-1}, 43.84±0.52 to 36.52±0.47 mg 100 g^{-1} and 43.32±0.45 to 34.46±0.37 mg 100 g^{-1}, respectively, from the 2nd to the 12th day of storage. There was a significant ($p \le 0.05$) difference between the total chlorophyll content of control chillies and chillies dipped for 1, 3 and 5 min (Table 2).

Reduction in chlorophyll content is an ordinary process occurring during the ripening of fruit. This drop in pigmentation helps in the visual discrimination of fruit at various stages of fruit ripening. A decline in total chlorophyll content was seen in control chilli samples. The change in the chlorophyll content on the coated chilli was not significant until the 8th day of storage due to the restricted activity of chlorophyll degrading enzymes. The possible cause for the reduction in chlorophyll content is an acceleration in the activities of chlorophyll digesting enzymes such as chlorophyllase, chlorophyll oxidase and peroxidase during maturation (Chaple *et al*., 2016). Comparable results were seen in the case of chillies coated with shellac-based coatings (Chitravathi *et al*., 2014).

The ascorbic acid content of control chillies ranged from 48.27±0.25 to 23.47±0.38 mg 100 g^{-1} and that of chillies dipped for 1, 3 and 5 min varied from 50.36±0.46 to

Table 2. pH and total chlorophyll content values of control and coated green chillies

Days	pH				Total chlorophyll content (mg 100 g^{-1})			
	Control	Coated			Control	Coated		
		1 min	3 min	5 min		1 min	3 min	5 min
2	5.68±0.22a	5.62±0.53b	5.59±0.46b	5.61±0.15b	40.52±0.36a	43.24±0.51b	43.84±0.52c	43.32±0.45b
4	5.73±0.41a	5.65±0.22b	5.62±0.24b	5.64±0.32b	36.87±0.42a	42.67±0.33b	43.38±0.34c	42.86±0.34b
6	5.78±0.18a	5.67±0.61b	5.62±0.44b	5.65±0.53b	32.57±0.38a	41.94±0.47b	42.78±0.51c	42.15±0.38b
8	5.82±0.51a	5.71±0.16b	5.63±0.28c	5.68±0.35b	28.74±0.29a	40.37±0.53b	42.14±0.23c	41.58±0.55d
10	5.86±0.28a	5.76±0.47b	5.68±0.43c	5.73±0.43b	23.47±0.46a	38.42±0.37b	40.21±0.43c	39.66±0.43d
12	5.98±0.36a	5.84±0.33b	5.70±0.25c	5.78±0.22d	14.46±0.32a	32.25±0.44b	36.52±0.47c	34.46±0.37d

Explanations as in Table 1.

Table 3. Ascorbic acid and total phenolic content values of control and coated green chillies

Days	Ascorbic acid (mg 100 g^{-1})				Total phenolic content (mg gallic acid equivalent 100 g^{-1})			
	Control	Coated			Control	Coated		
		1 min	3 min	5 min		1 min	3 min	5 min
2	48.27±0.25a	50.36±0.46b	50.86±0.45c	50.46±0.37b	158.95±0.27a	157.82±0.23b	156.85±0.18c	157.32±0.21b
4	45.77±0.43a	49.20±0.72b	49.82±0.55c	49.64±0.63c	160.25±0.36a	158.23±0.37b	157.27±0.27c	157.86±0.32b
6	34.24±0.32a	47.59±0.25b	48.76±0.36c	48.25±0.21d	162.54±0.57a	158.42±0.49b	157.82±0.42c	158.25±0.46b
8	30.27±0.28a	45.25±0.48b	46.89±0.22c	46.29±0.42d	164.76±0.62a	159.43±0.56b	158.47±0.44c	158.95±0.52c
10	26.19±0.53a	44.17±0.64b	45.62±0.43c	44.82±0.55d	165.92±0.76a	161.25±0.44b	159.26±0.32c	160.87±0.39b
12	23.47±0.38a	38.70±0.16b	39.86±0.12c	39.27±0.66d	168.82±0.84a	164.65±0.24b	160.77±0.18c	163.860±0.21b

Explanations as in Table 1.

38.70±0.16 mg 100 g^{-1}, 50.86±0.45 to 39.86±0.12 mg 100 g^{-1} and 50.46±0.37 to 39.27±0.66 mg 100 g^{-1}, respectively, from the 2nd to the 12th day of storage. There was a significant difference ($p \leq 0.05$) between the ascorbic acid content of control chillies and chillies dipped for 1, 3 and 5 min during storage – as shown in Table 3. The level of ascorbic acid in green chillies are controlled by the genotypic variations, pre-harvest climate conditions, maturity and post-harvest handling methods. The green chillies dipped in the composite coating for 3 min had the maximum ascorbic acid value of 39.86±0.12 mg 100 g^{-1}, followed by chillies dipped for 1 and 5 min, while the lowest value was observed in control chillies at 23.47±0.38 mg 100 g^{-1}, on the 12th day of storage. This last is owing to the early ripening of control chilli samples. The oxidative degradation of ascorbic acid is triggered by the presence of light, oxygen, heat, peroxides and biocatalysts like ascorbate oxidase or peroxidase (Chitravathi *et al*., 2014).

Phenolics hold an extensive spectrum of biochemical activities. These are the secondary metabolites in fruit and vegetables. They show antioxidant activity that permits them to scavenge both active oxygen species and electrophiles, as well as chelate metal ions. They possess the capability for autoxidation with regard to certain cellular enzyme activities (Chaple *et al.,* 2016). There was a gain in the total phenolic content of control chillies, due to the transformation of flavonoids to secondary phenolic compounds (Chitravathi *et al*., 2014). The total phenolic content of control chillies ranged from 158.95±0.27 to 168.82±0.84 mg gallic acid equivalent 100 g^{-1}, and that of chillies dipped for 1, 3 and 5 min varied from 157.82±0.37 to 164.65±0.24 mg gallic acid equivalent 100 g^{-1}, 156.85±0.18 to 160.77±0.18 mg gallic acid equivalent 100 g^{-1} and 157.32±0.21 to 163.86±0.21 mg gallic acid equivalent 100 g^{-1}, respectively, from 2nd day to the 12th day of storage. There was a significant change ($p \leq 0.05$) in the total phenolic content between the control chillies and the chillies coated for 1, 3 and 5 min (Table 3).

Table 4. Firmness and Colour value L* of control and coated green chillies

Days	Firmness (Newton)				L*			
	Control	Coated			Control	Coated		
		1 min	3 min	5 min		1 min	3 min	5 min
2	2.26±0.32a	2.62±0.19b	3.01±0.64c	2.68±0.45b	32.85±0.29a	31.46±0.49b	30.82±0.26c	31.22±0.65b
4	2.14±0.45a	2.49±0.38b	2.98±0.25c	2.57±0.53b	35.42±0.43a	31.76±0.73b	31.24±0.42c	31.54±0.34b
6	1.80±0.18a	2.32±0.74b	2.68±0.43c	2.48±0.35d	38.27±0.64a	32.64±0.45b	31.45±0.34c	32.18±0.46d
8	1.38±0.53a	1.79±0.35b	2.38±0.56c	2.16±0.23d	41.54±0.25a	34.25±0.63b	33.24±0.36c	33.76±0.75d
10	1.03±0.68a	1.62±0.17b	2.00±0.35c	1.85±0.46d	43.68±0.66a	36.85±0.47b	35.77±0.57c	36.24±0.36d
12	0.85±0.41a	1.46±0.54b	1.83±0.24c	1.61±0.62d	44.87±0.54a	39.27±0.49b	38.27±0.13c	38.85±0.28d

Explanations as in Table 1.

Table 5. Colour values a* and b* of control and coated green chillies

Days	a*				b*			
	Control	Coated			Control	Coated		
		1 min	3 min	5 min		1 min	3 min	5 min
2	-8.64±0.42a	-10.48±0.53b	-10.84±0.32c	-10.65±0.38b	28.47±0.29a	25.92±0.14b	25.02±0.47c	25.54±0.28c
4	-6.48±0.37a	-9.22±0.28b	-10.28±0.52c	-9.76±0.18d	30.97±0.37a	26.88±0.42b	25.82±0.37c	26.43±0.44d
6	3.87±0.17a	-8.46±0.43b	-9.75±0.35c	-9.24±0.52d	34.46±0.45a	28.16±0.61b	26.87±0.27c	27.86±0.56d
8	10.54±0.27a	-6.26±0.34b	-7.88±0.29c	-7.25±0.38d	38.85±0.16a	29.35±0.49b	28.15±0.65c	28.87±0.42d
10	14.76±0.34a	-4.37±0.15b	-5.22±0.31c	-3.87±0.47d	42.57±0.43a	32.46±0.54b	30.26±0.44c	30.87±0.32d
12	19.87±0.23a	4.89±0.31b	-3.87±0.25c	1.47±0.17d	48.76±0.32a	35.46±0.48b	33.27±0.19c	33.95±0.52d

Explanations as in Table 1.

The prominent factors that cause a decline in the market demand of chillies are the wilting and loss of moisture (Kader, 1993). The cell wall of plant tissues provides the rigidity and texture to the chillies. The changes in texture can be owing to the moisture loss through transpiration and enzymatic changes. The firmness of control chillies ranged from 2.26±0.32 to 0.85±0.41 N, and that of chillies dipped for 1, 3 and 5 min varied from 2.62±0.19 to 1.46±0.54 N, 3.01±0.64 to 1.83±0.24 N and 2.68±0.45 to 1.61±0.62 N, respectively, from the 2nd to the 12th day of storage. There was a significant difference ($p \leq 0.05$) between the firmness of control chillies and chillies dipped for 1, 3 and 5 min, as depicted in Table 4. The higher retention of firmness in coated chilli samples is due to the restriction of metabolic activities associated with fruit wall degrading enzyme such as ß-galactosidase (Chitravathi *et al*., 2014).

The peel colour of the chillies changed considerably during the storage. The coated chillies exhibited an overall retardation in the progression of colour change, thus retaining the ideal colour traits. As the chillies ripened, there was an increase in the L* value. The L* value of control chillies ranged from 32.85±0.29 to 44.87±0.54, and that of chillies dipped for 1, 3 and 5 min varied from 31.46±0.49 to 39.27±0.49, 30.82±0.26 to 38.27±0.13 and 31.22±0.65 to 38.85±0.28, respectively, from the 2nd to the 12th day of storage. There was a significant difference ($p \leq 0.05$) in L* value between control chillies and chillies dipped for 1, 3 and 5 min (Table 4). There was also an increase in a* value from negative to positive, indicating their colour change from green to red that is owing to the associative increase in the synthesis of carotenoids as a result of the transformation of chloroplast to chromoplasts (Chaple *et al*., 2016). The a* value of control chillies ranged from -8.64±0.42 to 19.87±0.23, and that of chillies dipped for 1, 3 and 5 min varied from -10.48±0.53 to 4.89±0.31, -10.84±0.32 to -3.87±0.25 and -10.65±0.38 to 1.47±0.17, respectively, from the 2nd to the 12th day of storage. There was a significant variation ($p \leq 0.05$) between the a*values of the control chillies and the chillies dipped for 1, 3 and 5 min (Table 5). A rise in the b* values for both the control and coated chillies was recorded; however, there was delayed progression of yellowness in the coated chillies. The b* value of control chillies ranged from 28.47±0.29 to 48.76±0.32, and that of chillies dipped for 1, 3 and 5 min varied from 25.92±0.14 to 35.46±0.48, 25.02±0.47 to 33.27±0.19 and 25.54±0.28 to 33.95±0.52, respectively, from the 2nd to the 12th day of storage. There was a significant variation ($p \leq 0.05$) between the b* values of control chillies and chillies coated for 1, 3 and 5 min (Table 5). Similar variation in the colour coordinates was reported by Chitravathi *et al.* (2014).

Capsaicin is an alkaloid (8 methyl-N-vanillyl-6-nonenamide) compound that brings about the pungency of the chilli. Its production increases with maturity (Iwai *et al*., 1979). There was no significant alteration in the capsaicin content of green chilli samples coated for 1, 3 and 5 min. The capsaicin content of control chillies increased as the phenolic content increased during its ripening. There was no significant ($p > 0.05$) rise in the capsaicin content in the coated chilli samples (Table 6). This indicated that the composite edible coating delayed the ripening of green chillies, thereby retarding the production of capsaicin.

A scanning electron microscopy was used to understand the microstructure of control and coated chilli skin surface with 1, 3 and 5 min dipping. Figure 1a depicts the SEM picture of control chilli skin exterior. In Fig. 1b, the composite coating is not uniformly distributed onto the skin surface *i.e.,* chilli skin with 1 min dipping. In Fig. 1c, the composite coating is uniformly distributed onto the skin surface *i.e.,* chilli skin with 3 min dipping. In Fig. 1d, the composite

Table 6. Capsaicin content (mg g^{-1}) of control and coated green chillies

Days	Capsaicin content (mg g^{-1})			
	Control	Coated		
		1 min	3 min	5 min
6	34.88±0.46a	32.61±0.27b	32.53±0.45b	32.85±0.23b
12	39.32±0.54a	33.05±0.34b	32.78±0.18b	33.19±0.41b

Explanations as in Table 1.

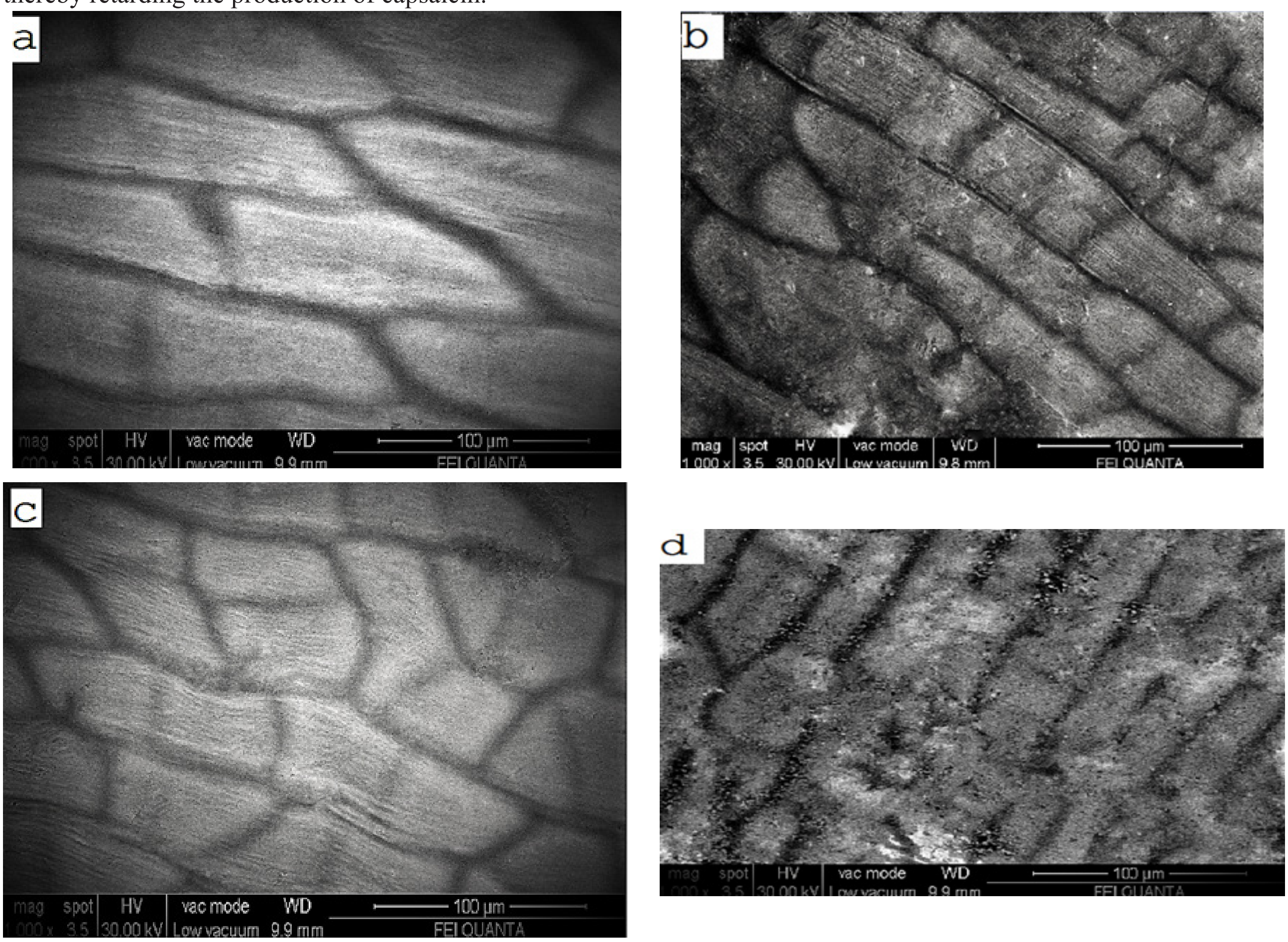

Fig. 1. SEM image of chilli skin: a – control, b – coated with 1 min dipping time, c – coated with 3 min dipping time, d – coated with 5 min dipping time: a – depicts the SEM picture of control chilli skin exterior; b – the composite coating is not uniformly distributed onto the skin surface, *i.e.* chilli skin with 1 min dipping; c – the composite coating is uniformly distributed onto the skin surface, *i.e.* chilli skin with 3 min dipping; d – the composite coating is not clearly visible because of greater thickness of the coating that is formed on the skin surface, *i.e.* chilli skin with 5 min dipping.

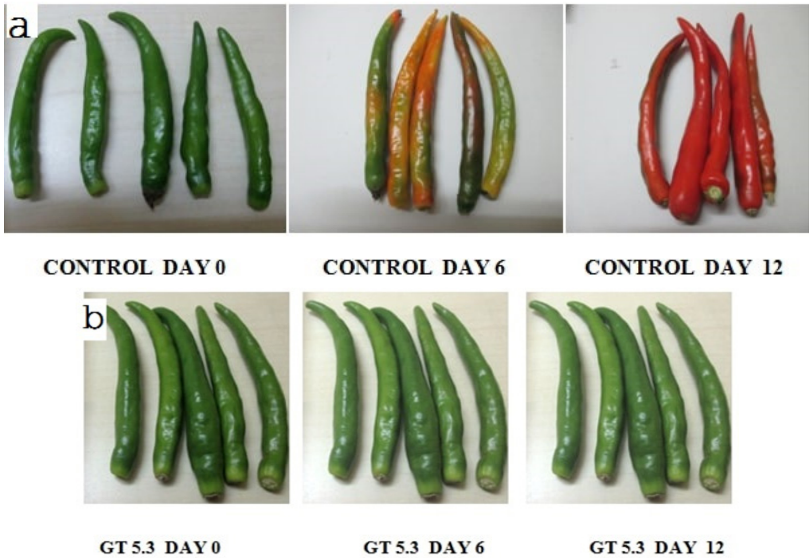

Fig. 2. The general appearance of the green chilli on day 0, 6 and 12 of storage at ambient conditions: a – control, b – coated with 3 min dipping time. The changes in the general appearance of the control chillies and optimised coated chillies with 3 min dipping time on day 0, 6 and 12 of storage.

Table 7. Sensory analysis of coated and control green chillis

Sample		Colour	Appearance	Firmness	Smell	Overall acceptability
Control		4.17±0.76a	5.24±0.85a	3.97±0.88a	6.42±0.72a	5.42±0.89a
Coated chillies (min)	1	5.25±0.65b	6.34±0.76b	5.48±0.54b	6.97±0.35b	6.32±0.56b
	3	8.25±0.46c	8.86±0.57c	8.54±0.48c	8.32±0.32c	8.44±0.45c
	5	7.15±0.84d	7.66±0.89d	6.88±0.79d	7.82±0.82d	7.47±0.86d

Explanations as in Table 1.

Table 8. Sensory analysis of spicy dip chutney made from control chillies and optimised chilli sample

Sample	Colour	Appearance	Taste	Pungency	Smell	Overall acceptability
Control	7.17±0.76a	7.24±0.85a	6.15±0.58a	7.87±0.88a	6.42±0.72a	6.24±0.89a
Coated chillies (3 min)	5.25±0.65b	6.34±0.76b	7.82±0.74b	6.48±0.54b	6.97±0.35b	7.32±0.56b

Explanations as in Table 1.

coating is not clearly visible because of the greater thickness of the coating that is formed on the skin surface, *i.e.,* the chilli skin with 5 min dipping.

The alterations in the external appearance of chillies arise due to the water loss that progresses during its storage. Ochoa *et al*. (2011) noted that the use of coatings synthesised from candelilla wax retarded changes in the appearance of apples. These changes can be due to alteration of the fruit internal atmosphere, with a high concentration of carbon dioxide and minute levels of oxygen, that decelerates the process of weakening (Ochoa-Reyes *et al*., 2013). The changes in the general appearance of the control chillies and optimised coated chillies with 3 min dipping time on day 0, 6 and 12 of storage (Fig. 2).

The sensory evaluation of both control and coated chillies was performed on the 12th day of storage using the 9 points hedonic scale. Factors such as appearance, colour, flavour, smell and overall acceptability were assessed so as to study the influence of the coating on the sensory attribute of the chillies. The above parameters were tested by the 20-panel members. There was significant variation ($p \leq 0.05$) in the sensory parameters between control chillies and chillies coated for 1, 3 and 5 min, as depicted in

Table 7. The sensory evaluation of the spicy dip chutney made from the optimised coated chilli, in comparison to the chutney made with uncoated chillies, clearly reveals that the coating did not add any off-flavour and also that the coating was efficient in retarding the production of capsaicin (Table 8).

CONCLUSIONS

1. The green chillies coated with gum Arabic (5%)-thyme oil (0.5%) edible coating with 3 min dipping time exhibited a significant reduction in difference in the physico-chemical parameters such as weight loss, total soluble solids, colour, ascorbic acid, firmness and pH at room temperature storage (28±2ºC).

2. The sensory analysis of control and coated green chillies showed that the composite coating with 3 min dipping time was effectual in preserving the organoleptic properties of the chillies up to 12 days of room temperature storage, when compared to that of control chillies that had acceptable organoleptic properties until the 6th day of storage.

Conflict of interest: The Authors do not declare conflict of interest.

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