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Controlling of post harvest losses of selected Leafy vegetables and green chilies by coating with plant mucilage of *Terminalia arjuna* (Kumbuk)

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Abstract
The objective of the present study was to investigate the possible application of the edible grade plant mucilaginous of *Terminalia arjuna* (Kumbuk) over selected high respiratory leafy vegetable and green chilies as a thin coat. In this study five types of high respiratory vegetables; *Centella asiatica* (Gotukola), *Alternanthera sessilies* (Mukunuvenna), *Ipomoea aquatic* (Kankun), *Capsicum annum* (Green chilies) and *Allium ampeloprasum* (leeks) were taken and coated with mucilaginous materials extracted from *Terminalia arjuna* (Kumbuk). The selected vegetables were coated with Kumbuk and their keeping quality, weight loss, cumulative inedible percentage, colour measurement (L*A*B*), were determined and results were compared with the control sample. Green chilies could be kept for 14 days in open environment with very good organoleptic properties with the Kumbuk mucilage. Gotulola and leeks with Kumbuk mucilage were able to kept 5 and 4 days respectively. The weight losses of the Green chilies, Leeks, and Gotukola were reduce by considerable amount with the mucilage.

Keywords: edible, kumbuk, mucilaginous, *Terminalia arjuna*

1. Introduction
Post-harvest loss is the sum of all losses encountered through the production and distribution chain [1]. The world population is increasing faster than the growth of food supply and the resources used for creating foods are becoming increasingly scarced. Reducing post harvest losses must be an essential to make more food available without increasing the burden on the natural environment [2]. There are many bio chemical process which are directly associated with the post harvest degradation of the vegetables. Respirations as well as diffusion through the cuticle on the skin are involved for the water loss [3] Mucilages are very often used in various industries. Vast application of plant mucilages and gums in various industries is because of low cost, ready availability and important properties which they confer on products. In recent years, plant gums and mucilages have evoked tremendous interest due to their diverse pharmaceutical applications such as diluents, binders, disintegrants in tablets, thickeners in oral liquids, protective colloids in tablets, thickeners in oral liquids, protective colloids in suppository [4]. The rates of water loss and respiration are dependent on maturity at harvest, source of produce, season and storage conditions. Traditionally, films and coatings have been used to reduce water loss [5]. *Terminalia arjuna* (Arjuna) tree is about 60-80 feet in height, and is seen along rivers, streams, and dry water bodies throughout the Indo-sub-Himalayan tracts of Uttar Pradesh, southern Bihar, Chota Nagpur, Burma, Madhya Pradesh, Delhi, and Deccan region. It is also found in the forests of Sri Lanka and Mauritius [6]. Aqueous extract of *T. arjuna* contains 70% polyphenols having a molecular weight greater than 3.5 kDa and they are confirmed by the HPLC and LC-MS. The aqueous extract contains flavon-3-ols, such as (+)-catechin, (+)-gallocatechin and (−)-epigallocatechin; gallic acid, ellagic acid and its derivatives such as 3-O-methyl ellagic acid 4-O-β-d-xylopyranoside and 3-O-methyl ellagic acid 3-O-rhamnoside [7]. Therefore this study was focused on to evaluate application potential of selected natural mucilaginous gums as a film coating material which is acted as a barriers to respiration and transpirations

2. Materials and Methods
2.1 Collection of plant materials
Leaves of Kumbuk (*Terminalia arjuna*) were collected from Kalutara, Sri Lanka.

2.2 Collection of vegetable varieties
Five types of high respiratory vegetable varieties were collected from the local market and subjected to the study. Those are Gotuloka*(Centella asiatica)*, Mukunuvenna (*Alternanthera sessilis)*, Kankun (*Ipomoea aquatic)*, Leaks *(Allium schoenoprasu)*, Green chili (*Capsicum annum*).

2.3 Extraction of mucilaginous materials from Kumbuk leaves.
Fresh matured Kumbuk leaves were initially washed and air dried. The extraction of mucilaginous materials was carried out by making the minor modifications to the procedure developed by [8]. One hundred grams of leaves from each mucilaginous material source were taken and steam blanched in 1% SMS solution for 10 minutes. Just after blanching leaves were washed with cold distilled water. Leaves were mashed manually in 1% citric acid solutions (leaves: water 1:10 ratio). The Extract was filtered through six layers of muslin cloths. 500 ml of mucilaginous material solutions were prepared by the mucilaginous source.

2.4 Preparation of mucilage treated vegetable samples

The application of gum was done by dipping the vegetables in a very dilute mucilaginous solution for 30 seconds and letting them to drain.

For the Gotukola, Mukunuvenna and Kankun

Initially 30 g of cleaned green leafy vegetable samples were prepared as bundles and the bundles were dipped in mucilaginous material solutions separately for 30 seconds. Control sample was dipped in distilled water for 30 seconds. Then the excess mucilaginous gum was drained off properly. The coated leaves bundles were dried in a force air dryer at 25^0 C for 30 minutes. Then the dried leaves bundles were packed in polyethylene bags and were sealed and kept under ambient conditions (Temperature -25 ^{0}C and 85% RH). All polyethylene bags were punctured to get five holes to facilitate the air movement. Thereafter weight loss and keeping quality of each vegetables (how long leafy vegetables were taken to turn yellowish color) were recorded daily. All treatment were triplicated.

For green chilies

Well matured green chili pods at same size were taken and the weight of the samples were recorded and the same procedure done for green leaves were carried out.

For leeks

Leeks trees at the same size were washed with distilled water and the same procedure done for green leaves were carried out.

2.5 Determination of the weight losses of the mucilaginous material coated vegetable samples and control samples.

Coated and control samples were kept in ambient conditions (30^0C and RH 85%) while one sample was keeping in the refrigerator. A thereafter weight loss of each sample was recorded daily.

2.6 Determination of cumulative inedible post-harvest loss of mucilaginous materials coated vegetable samples and control samples.

Coated and control vegetables samples were kept under ambient condition (25^0C and RH 85%) while keeping another sample in a refrigerator. Thereafter the inedible part (the parts which has been turned into yellowish colour) of the each samples were removed and the cumulative weight of the inedible parts were calculated daily until the whole sample become totally inedible.

2.7 Analysis of the colour variation of the mucilaginous material coated vegetable samples and control samples.

The colour of each samples were determined by the chromo meter (Konia Minolta, CR – 400 head) and the L*a*b* colour values were taken.

3. Results and Discussion

3.2 Determination of weight losses of vegetable samples coated mucilaginous materials.

When *centilla* is concerned the highest weight loss was occurred in the control sample which was around 58.1% - 59.30% and the lowest loss occurred in the sample kept under refrigerated condition which is around 21%. The weight loss for coated samples was 39.10% - 42.30%.The appearance of the refrigerated sample was good after the 10 days of storage time since their respiration rate had been reduced. The weight loss mainly happens due to the respiration and the transpiration of the plant tissues. By the created micro film over the leaves it reduced air movement through the surface while limiting the respiration rate of the Gotukola. As respiration rate is a major indicator of post-harvest produce metabolism, factors which affect this rate are the main consideration in post-harvest preservation of fresh fruit and vegetables. Many technologies for preserving fresh produce involve respiration by manipulating environmental conditions (E.g.-: low temperature and modified atmosphere of low O_2 and high $C0_2$) [9].When Green Chili is concerned the highest weight loss was observed in the control sample which was around 32.3% and the lowest weight loss (13.3%) occurred in the samples which kept under refrigerated condition and in the coated sample the loss was around 18.0%. Green chilies were able to keep for 14 days with the coating with very good organoleptic properties. The chili sample kept in the refrigerator was not much edible condition because dark colour patches were occurred on the surface of the chili pods. Surface discolorations and the green colour patches occurred because of the chilling injuries which are occurred when the chilies are kept under very low temperatures. When Mugunuwenna is concerned the highest weight loss was observed in the control sample which was around 16.6 %. The lowest weight loss (5.30%) was given by the refrigerated sample. The mucilage coated sample also showed low weight loss (11.60%) compared to the other samples. The keeping qualities of the Mukunuvenna with the mucilaginous coating was not much successful since almost all the leaves had been de greened after 3 days while resulting good organoleptic qualities of the sample kept in the refrigerator. When Leeks is concerned the highest weight loss was given by the control sample which is around 48.6 % - 50% while the lowest weight loos was given by the refrigerated sample which was around 13.6 - 15%. The weight loss of the coated samples was 21.0%-22.30%. When Kankun is concerned the highest weight loss was given by the control sample which is around 11.6 % - 13%.The lowest weight loss was by the refrigerated sample which was around 5% and weight loss of the coated sample was around 8.30%-9.6%. The reason for this consequence is plant mucilage materials capable to form microfilm over the leaf and this film is capable to act as an additional layer over the leaf while partially or fully covering the stomata. Hence evapo transpiration as well as the rate of respiration of produces can be reduced to a great extent. Hydrocolloid films have desirable barrier properties for gas /moisture and good mechanical characteristics have long been known to protect perishable food products from deterioration by retarding dehydration, suppressing respiration, improving textural quality, helping to retain volatile flavor compounds and reducing microbial growth [10].

3.3 Evaluation of cumulative inedible percentage of the vegetable samples coated with mucilaginous materials against the control

When *Centilla* is concerned the highest inedible percentage is shown by the control sample. The least value was recorded by the sample which was kept in refrigerated condition and the coated sample which were around 11.0% and 30.0 % respectively. In here mainly respiration cause for the turning the colour of the vegetable into yellowish. If the respiration is high it indicated the degradation process is also high. Other than that there is a great impact of the ethylene on vegetable post-harvest degradation process. By this micro film which was created over the produce, it minimize the chance to connect ethylene and ethylene receptors while covering the receptors. When Green Chili is concerned the cumulative inedible percentage was highest in the refrigerated sample which was around 28%.The control sample showed 22.6% inedible percentages while the lowest inedible loss percentage was given by the coated sample which was around 10.2% after 22 days of storage time. The reason for this consequence is the chilling injuries which occurred in some chilling sensitive fruits and vegetables when they are stored at the very low temperatures. The cell wall is damages of the commodity and hence the discolorations are occurred. Because of this discolored parts were occurred at the green chilies which resulting a highest inedible loss of the refrigerated sample. When Mugunuwenna is concerned the lowest inedible loss was given by the refrigerated sample which was around 22.0%.The coated sample resulted the inedible percentage as 39.0%. According to the results the best method for keeping Mukunuvenna was the refrigerated condition and coating by mucilaginous materials was not an effective method to extend the post-harvest life of Mukunuvenna. The coating by the plant mucilaginous materials for extension of the shelf life of Mukunuvenna was not successful since almost all the leaves had become de greened when stored for 3 days. When the cumulative inedible portion of Leeks is concerned, the loss was highest in the control sample which is around 25.0%.The least loss was recorded by the sample which was kept in refrigerated condition and the coated sample was around 16.0 % respectively. When Kankun is concerned it was observed that there is no significant difference between the mucilaginous coated and non-coated samples of the water spinach ($p<0.05$) The refrigerated sample was given very low inedible percentage compared to the other samples.

3.3 Analysis of the colour variation of the mucilaginous material coated vegetable samples and control samples.

L A B values of vegetable samples were taken initially and after some days of treatment.

3.3.1 L* A* B* values for *centella* initially and after 10 days of treatment are shown in Table 1.

Table 1: L* A *B* values of *centellainitially and after ten days*

Sample	Stage	L*		A*	B*	
Control	Initial	26.1	±0.1	-12.6 ± 0.1	26.9	±0.05
	Final	60.03	± 0.05	-6.5 ± 0.05	50.16	± 0.05
Coated	Initial	29.80	±0.1	-12.6± 0.1	29.8	± 0.1
	Final	40.1	± 0.1	-8.2 ±0.05	40.1	± 0.1
Refrigerated	Initial	27.3	± 0.15	-12.6 ± 0.1	27.3	±0.15
	Final	35.5	±0.11	-10.2±0.05	32.3	± 0.05

When considering the L*a*b* values of the table 1 the L value increases gradually since it indicates the lightness of the sample. At the beginning all the *centella* samples had the L* value around 26 -27.When the Gotukola is kept for days it turns into yellowish colour due to the degreening process of the chlorophylls. The lightness of the sample (L value) is increased gradually. When considering the A* value of the final stage (Turning point into the inedible condition) the largest A* value was 60.03±0.05 of the control sample and has turned significantly yellowish. Refrigerated samples had the final L value 35.5±0.11 and the coated sample showed L value of 40.1± 0.1 with the good edible appearance. The a value (-a value) of the sample gradually comes to the positive side (reduce the minus value) since it is indicated the green colour of the sample. When the green color is reduced the - a value comes to the positive.

3.3.2 L* A* B* values for Green chili initially and after 22 days of treatment are shown in Table 2.

Table 2: L* A* B* values of Green chili initially and after 22 days

Sample	Stage	L*		A*	B*	
Control	Initial	26.5	±0.1	-9.56± 0.05	15.23	±0.06
	Final	39.3	± 0.1	-2.5 ± 0.1	29.57	± 0.32
Coated	Initial	26.50	± 0.2	-9.5± 0.1	15.56	± 0.2
	Final	31.3	± 0.05	-4.0 ±0.15	24.9	± 0.1
Refrigerated	Initial	26.5	± 0.2	-9.6 ± 0.15	15.3	±0.1
	Final	11.5	±0.1	-4.9±0.1	20.2	± 0.2

When considering the L*A*B values of the table 2 it is indicated that all the chili samples had the L* vales in the range of 26 – 27 initially.After 22 days the control sample had become yellowish colour and some green chilies had ripen. The highest L* value has given by the control sample. And the lowest L* values has given by the refrigerated sample. In the

case of refrigerated sample those green chilies had been subjected to the chilling injuries and there were many discoloured patches of the green chilies. According to the B* values the highest B* value was given by the control sample around 2.57± 0.32 while lowest B* value was indicated by the refrigerated sample around 20.2±0.2 value. According to the A* values the highest greenness value (A*) was given by the refrigerated sample.

3.3.3 L* A* B* values for *Alternanthera sessilis* initially and after 3 days of treatment are shown in table 3.

Table 3: L*A*B* values of *Alternanthera sessilis*initially and after 3 days

Sample	Stage	L*		A*	B*	
Control	Initial	32.0	±0.5	-12.4± 0.2	13.5	±0.1
	Final	51.8	± 0.3	-6.1 ± 0.1	46.3	± 0.2
Coated	Initial	35.5	± 0.1	-11.5± 0.05	13.5	± 0.1
	Final	49.5	± 0.3	-6.7 ±0.1	42.3	± 0.17
Refrigerated	Initial	33.6	± 0.0	-12.5± 0.1	13.5	±0.1
	Final	42.2	±0.2	-10.5±0.1	30.2	±0.0

According to the table 3 the highest L* value was for control sample and the lowest L* value was around 42.2 ±0.2 which was the refrigerated sample. When considering the A* values the lowest A* value was given by the refrigerated sample which was around -10.5±0.1while the highest A* value was given by the control sample around -6.1 ± 0.1. According to the B* values the highest B* value was given by the control sample around 46.3 ± 0.2 while lowest B* value was indicated by the refrigerated sample around 30.2±0.0 value. The lightness of the control sample had been increased rapidly. According to the A* values the highest greenness value (A*) was given by the refrigerated sample. According to the colour measurement values the best sample was the refrigerated sample and the coating with mucilaginous material was not given good results into satisfactory level.

3.3.4 L* A* B* values for *Allium schoenoprasu*initially and after 3 days of treatment are shown in Table 4.

Table 4: L* A* B* values of*Allium schoenoprasu* initially and after 9 days

Sample	Stage	L*	A*	B*
Control	Initial	36.7±0.5	-8.2± 0.1	10.2±0.1
	Final	60.1± 0.1	-5.3± 0.1	34.2± 0.2
Coated	Initial	36.5± 0.05	-8.1± 0.1	10.16± 0.15
	Final	48.5± 0.1	-5.6±0.0	29.4± 0.28
Refrigerated	Initial	36.2± 0.6	-8.2± 0.05	10.5 ±0.1
	Final	40.36±0.15	-7.1±0.05	18.4±0.1

According to table 4 it is indicated that the initial L* values of the leaks samples were around 36.5.The highest L* value of after the 9 days was 60.10 from the control sample and the lowest L* value was around 40.36 ± 0.15 which was the refrigerated sample. The coated sample was given lower L* value which was closer to the refrigerated sample. When considering the A* values the lowest A* value was given by the refrigerated sample which was around -7.1±0.05 while the highest A* value was given by the control sample. According to the B* values the highest B* value was given by the control sample around 34.2± 0.2 while lowest B* value was indicated by the refrigerated sample around 18.4±0.1 value.

3.3.5 L* A* B* values for water spinach initially and after 3 days of treatment are shown in table 5.

Table 5: L*A*B* values of water spinach initially and after 3 days of treatment

Sample	Stage	L*	A*	B*
Control	Initial	30.1±0.05	-10.2± 0.2	15.1 ±0.05
	Final	53.3± 0.05	-6.4 ± 0.1	45.5± 0.2
Coated	Initial	30.1±0.1	-10.5± 0.05	15.2 ±0.1
	Final	51.6± 0.3	-7.6 ± 0.1	43.6± 0.1
Refrigerated	Initial	30.1± 0.1	-10± 0.05	15.4±0.1
	Final	38.1±0.1	-8.4±0.1	22.4±0.5

According to the table 5 it is indicated that all the samples had the L* vales around 30.1.The highest final L* values was given by the control sample which was around 53.3 ± 0.05.The lowest L* value was given from the refrigerated sample which was around 38.1 ± 0.1. When considering A* value the control samples gave 6.4 ± 0.1 as the lowest L* values. When considering the B* values the lowest B* value has given by the refrigerated samples around 22.4 ± 0.05.

The colour is very critical for any vegetable which directly affect to the consumer acceptance of the commodity. In green vegetables, the senescence process usually leads to a yellow colouration of the tissue, because of the degradation of chlorophylls and the formation of pheophytins. The maintenance high relative humidity, combined with atmospheres lowered in O2 and moderately enriched in CO_2, are shown to delay chlorophylls degradation [11].

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