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Development of an Edible Coating for Fresh Lime (*Citrus aurantifolia* Swingle) Fruits with Kithul Flour (*Caryota urens*) and Evaluate its Shelf- life

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***Abstract*—**Perishable nature of fresh fruits and vegetables causes to reduce their shelf-life; hence post-harvest losses are becoming a burning problem. Storing under control conditions may solve the problem, but it can't be practiced throughout food chain. The application of synthetic coating on fresh products became popular however, there are limitations due to food safety measures. Introducing edible coatings to improve the shel-flife of fresh products has become a new approach. Lime fruit is one of the highly demanded fruits and is used for various food processing applications. This study was carried out to develop a new edible coating to enhance the shelf-life of fresh lime using flour of "kithul" tree (Caryota urens) which has gelatinizing properties. Two concentrations (1% and 3%) of "kithul" flour were used. The coatings were equally applied on fruit surfaces except for the control. All samples were stored in both ambient (29 oC and 70% RH) and controlled (13 ^{o}C and 79% RH) storage conditions. Percentages of weight loss, peel colour changers, peel browning, disease, visual quality rating, total soluble solids, pH, and titratable acidity were recorded at four days interval in ambient storage and at seven days interval in temperature-controlled storage. According to the results, lime fruits treated with 1% kithul flour coating were recorded the longest shelf life of 12 days under ambient storage and 42 days under controlled storage. Therefore, this study highlights that 1% kithul flour formula can be introduced as an edible coating to prolong the shelf-life of fresh lime.

***Keywords*—**Caryota urens, Citrus aurantifolia, Edible coating, Shelf-life

I. Introduction

Lime (Citrus aurantifolia Swingle) belongs to the family Rutaceae and it is one of the most widely grown tropical fruit crops in Sri Lanka and has a high consumer demand all year around. The extent and production of limes in 2014 were 12138 ha and the yield was recorded as 5387 MT (Perera *et al*., 2015). Lime fruits are widely used in the culinary, medicinal, and food processing industries. The fruits are a rich source of carbohydrates, fibers, antioxidants, water, and vitamin C (Jamil *et al*., 2015).

The postharvest losses of fruits and vegetables have increased up to 30-40% in Sri Lanka (Rajapaksha, 2021). Major postharvest losses of lime fruits are caused due to weight loss, fungal diseases, and physiological damages were occurred due to inappropriate handling (Bisen *et al*., 2012). However, high price fluctuation can be seen throughout the year. During the off-season, the price is remained around Rs.1000/1kg and drastically dropped down to Rs. 50/1Kg in peak production. (Champa *et al*., 2020a).

It is important to find out safe, healthy, and environment-friendly methods to extend the shelf life of fresh limes which can be used in both seasonal and off-seasonal periods using plant-originated starch-based material.

Edible coatings are thin layers of edible material applied to the product surface to enhance the shelf life by reducing moisture losses and gas exchange (Dhall, 2013). Edible coatings can be made by using polysaccharides that originated from both animals and plants. Kithul flour extracted from kithul tree (Caryota urens) can be introduced as an alternative to gelatin. Palm starch is one of the cheapest and the most abundant sources of food, which shows the highest productivity per land area among other starch crops (Wijesinghe *et al*., 2015). Kithul flour has the potential to modify as a plant-origin gelatinizing agent. Although, kithul flour can be utilized as a substitute for existing plant origin gelling agents and stabilizers also as an emulsifier for food applications of vegetarians (Wijesinghe *et al*., 2015).

Corn oil is also a well-known plant-based product that has strong barrier properties though corn oil, itself can use as an edible coating for fruits (Alam *et al*., 2017). Sorbitol is used as a stabilizer to enhance the strength of the external coating (Backry *et al*., 2017). The objective of this study was to develop an edible coating with kithul flour and to evaluate the effect of the coating in enhancing the shelf life of fresh lime fruits under different storage conditions.

Table I: Treatment Combinations

Treatment	Kithul flour (g)	Corn oil (ml)	Sorbitol (g)
T1	0	0	0
T2	1	15	2
T3	3	15	2

II. MATERIALS AND METHODS

A. Material Collection

Lime fruit samples (Citrus aurantifolia Swingle) were obtained from a commercial orchard situated in Moneragala. Fruits were harvested manually at the green mature stage and transported in cardboard boxes to the laboratory on the same day. Fruits were selected based on the characters; free of physical damages and blemishes, uniformity in maturity, shape, size, and color (Champa *et al*., 2020b). Kithul flour and corn oil were purchased from a local supermarket. Analytical grade sorbitol was collected from the Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka.

B. Experimental Design and Treatments

Two gel concentrations were prepared by changing the kithul flour concentration (1% and 3%) and recorded the parameters in both ambient and cold conditions (Table I). A single factor analysis was conducted in a Complete Randomized Design (CRD) with five replicates per treatment.

C. Preparation of Coating Solution

Kithul flour was weighed and added into a beaker which contained 100 ml distilled water. The mixture was stirred and heated up to 65-75 ^{o}C, continue stirring until it converted to the gel formation. This is a minor modification of the procedure given by Wijesinghe *et al*. in 2015. Finally, corn oil and sorbitol were added and mixed well using a blender. Sorbitol was added as a stabilizer. The pH was adjusted to 3.2 by adding citric acid to facilitate gel formation.

D. Application of Treatments

The selected lime fruits were washed with clean water and air-dried at ambient temperature. Gel coatings were applied through spraying and allowed them to dry to form a thin layer around the fruit surface. The treated fruits were kept on trays and stored at the laboratory under ambient and cold storage conditions. Temperature and relative humidity were recorded regularly during the experimental period. The experiment was conducted during three months using 50 fruits for each treatment.

E. Percentage of Weight Loss (PWL%)

Percentage weight loss was calculated at a regular four days interval in ambient storage condition and seven days interval in cold storage conditions. Percentage weight loss was calculated separately for each treatment at regular time intervals by using the following formula. Each treatment was consisted of five replicates.

$$PWL\% = ((w_1 - w_2)/w_1) * 100 \quad (1)$$

W1- Initial weight W2- Final weight

F. Change of Peel Colour

The peel colour was measured using the Royal Horticultural Society colour chart (RHS, 2001) at four days intervals in ambient storage conditions and seven days intervals in cold storage conditions. Data was collected from five replicates.

G. Percentage of Peel Browning

The percentage of peel browning was recorded by visual observation and expressed as a percentage. It was determined as a number of fruits with off-colour patches on the surface relative to the total number of fruits in each treatment of both storage conditions (Champa *et al*., 2020b). Visual observation was taken from all five replicates.

H. Percentage Disease Incidence (PDI)

Percentage of disease incidence was recorded by visual observation and expressed as a percentage. It was determined as a number of infected fruits relative to the total number (150 fruits) of fruits in each treatment of both storage conditions (Champa *et al*., 2020b).

I. Visual Quality Rating (VQR)

The visual quality rating was determined by visual observation followed by a scale of acceptance. A five-point hedonic scale was used whereas, 5- excellent (green and fresh), 4- good (yellowish-green and fresh), 3- fair (yellow and fresh), 2- poor (yellow with brown patches, unmarketable, but affordable), and 1- worst (all brown) (Champa *et al*., 2020b).

J. Determination of Physiochemical Parameters

Titratable Acidity (TA) and Total Soluble Solids (TSS) were determined according to the procedures of the Association of Analytical Chemists (AOAC, 2005) at four days intervals in ambient storage conditions and seven days intervals in cold storage conditions until the overall acceptability becomes unsatisfactory for each treatment. The lime juice was extracted by squeezing and filtering the juice using a strainer. TA content was determined by acid-base titration, using 0.1N Sodium hydroxide (NaOH). TSS content of the juice samples was obtained using a handheld refractometer and pH was detected using digital pH meter.

K. Statistical Analysis

Parametric data were analysed using Analysis of variance (ANOVA). Visual quality rating data were analysed using a Kruskal Wallis test and changes of peel colour data were analysed using a Chi-Square test. Mean separation was conducted with Turkey's test using Minitab statistical software (version 18.1).

Table II: Variation of parameters of lime fruits under ambient storage conditions

Treatments	Storage Period (days)	PWL (%)	Peel Browning (%)	PDI (%)	pH	TSS (%)	TA (%)	Peel Colour	VQR
T1	0	-	0	0	2.08±0.00^{a}	7.98±0.06^{a}	8.21±0.02^{a}	G138A	5
	4	7.58±0.29^{a}	0	0	2.06±0.00^{b}	8.98±0.03^{a}	8.27±0.02^{a}	G141B	5
	8	12.03±0.51^{a}	7	0	2.06±0.00^{a}	9.88±0.05^{a}	8.36±0.02^{c}	YGN144A	4
	12	16.02±0.17^{a}	21	13	2.12±0.03^{a}	10.08±0.03^{a}	8.70±0.04^{a}	YG145A	3
	16	21.13±1.59^{a}	83	61	1.96±0.00^{b}	10.44±0.03^{a}	8.92±0.04^{a}	YG151A	2
T2	0	-	0	0	2.08±0.00^{a}	7.98±0.05^{a}	8.22±0.02^{a}	G138A	5
	4	3.42±0.11^{b}	0	0	2.10±0.00^{a}	8.91±0.03^{a}	8.24±0.02^{a}	G138A	5
	8	5.22±0.32^{b}	0	0	2.10±0.00^{a}	9.90±0.06^{a}	8.47±0.01^{b}	G137A	4
	12	9.01±0.19^{b}	5	1	2.14±0.00^{a}	9.84±0.07^{b}	8.57±0.04^{b}	G143A	4
	16	13.82±0.56^{b}	41	25	2.04±0.00^{a}	10.47±0.03^{a}	8.74±0.03^{c}	YGN144C	3
T3	0	-	0	0	2.08±0.00^{a}	7.98±0.02^{a}	8.22±0.02^{a}	G138A	5
	4	5.45±0.65^{c}	0	0	2.10±0.00^{a}	8.89±0.03^{a}	8.26±0.02^{a}	G138A	5
	8	9.06±0.23^{c}	0	0	2.08±0.04^{a}	9.89±0.03^{a}	8.54 ±0.02^{a}	G141A	4
	12	12.22±0.57^{c}	11	3	2.13±0.02^{a}	9.70±0.15^{b}	8.70±0.03	YG145A	4
	16	19.90±0.71^{a}	62	46	2.00±0.03^{ab}	10.48±0.01^{a}	8.81±0.03	YGN144A	3

T1-Uncoated fruits, T2- 1% kithul flour concentration, T3- 3% kithul flour concentration.At 0.05 confidence interval, means grouped with the same letters which are not significantly different. PWL- Percentage weight loss, PDI- Percentage disease incidence, TSS- Total soluble solids, TA- Titratable acidity, VQR- Visual quality rating.

Table III: Variation of parameters of lime fruits under cold storage conditions

Treatment	Storage periods (Days)	PWL (%)	Peel browning (%)	PDI (%)	pH	TSS (%)	TA (%)	Peel colour	VQR
T1	0	-	0	0	2.08±0.00^{a}	8.00±0.04^{a}	8.22±0.020^{a}	G138A	5
	7	4.93±0.13^{a}	0	0	2.10±0.01^{a}	8.83±0.04^{a}	8.21±0.01^{a}	G138A	4
	14	7.61±0.38^{a}	0	0	2.05±0.06^{a}	9.31±0.01^{a}	8.42±0.00^{a}	G138A	4
	21	9.76±0.09^{a}	0	0	1.97±0.01^{c}	9.62±0.01^{a}	8.91±0.01^{a}	G141B	4
	28	13.39±0.03^{a}	17	0	1.96±0.00^{c}	9.73±0.01^{a}	9.02±0.01^{a}	YG145A	3
	35	18.49±0.3^{a}	37	15	2.26±0.01^{a}	10.23±0.06^{a}	8.95±0.07^{a}	YG151A	3
	42	23.36±0.05^{a}	59	26	2.28±0.02^{a}	7.98±0.06^{a}	8.31±0.03^{a}	YGN144A	2
	49	*	*	*	*	*	*	*	1
T2	0	-	0	0	2.08±0.00^{a}	7.97±0.05^{a}	8.21±0.02^{a}	G138A	5
	7	2.51±0.02^{c}	0	0	2.10±0.01^{a}	8.83±0.01^{a}	8.22±0.01^{a}	G138A	5
	14	5.92±0.03^{c}	0	0	2.11±0.00^{a}	9.26±0.00^{b}	8.28±0.06^{b}	G138A	5
	21	7.54±0.04^{c}	0	0	2.01±0.00^{a}	9.53±0.01^{b}	8.32±0.01^{b}	G137A	5
	28	10.28±0.03^{c}	6	0	2.17±0.03^{a}	9.46±0.01^{b}	8.44±0.01^{b}	G143A	4
	35	14.47±0.07^{c}	16	5	2.22±0.02^{b}	9.65±0.01^{b}	8.56±0.08^{b}	G141B	4
	42	16.69±0.07^{c}	20	15	2.24±0.01^{b}	10.32±0.01^{b}	8.10±0.07^{b}	G141B	3
	49	18.72±0.08^{c}	36	46	2.23±0.02^{b}	10.54±0.01^{b}	7.83±0.01^{b}	YG151A	3
T3	0	-	0	0	2.08±0.00^{a}	7.98±0.02^{a}	8.35±0.32^{a}	G138A	5
	7	3.01±0.06^{b}	0	0	2.07±0.00^{a}	8.87±0.02^{a}	8.21±0.00^{a}	G138A	5
	14	6.55±0.38^{b}	0	0	2.08±0.05^{a}	9.27±0.01^{b}	8.30±0.03^{b}	G138A	5
	21	8.15±0.15^{b}	0	0	1.99±0.01^{b}	7.58±0.01^{a}	8.32±0.02^{b}	G143A	5
	28	11.79±0.04^{b}	9	0	2.08±0.00^{b}	8.66±0.05^{b}	8.42±0.05^{b}	G144A	4
	35	16.96±0.04^{c}	28	9	2.25±0.02^{ab}	9.69±0.02^{b}	8.74±0.04^{b}	YG144A	3
	42	19.77±0.11^{b}	37	18	2.26±0.01^{ab}	10.46±0.00^{a}	8.31±0.03^{a}	YG151A	3
	49	23.85±0.07^{b}	63	52	2.26±0.01^{a}	10.66±0.02^{a}	7.39±0.11^{c}	YG153B	2

T1-Uncoated fruits, T2- 1% kithul flour concentration, T3- 3% kithul flour concentration. At 0.05 confidence interval, means grouped with the same letters which are not significantly different. PWL- Percentage weight loss, PDI- Percentage disease incidence, TSS- Total soluble solids, TA- Titratable acidity, VQR- Visual quality rating.

III. RESULTS AND DISCUSSION

A. Percentage Weight Loss (PWL%)

Weight loss is the major postharvest loss causing factor in citrus fruits. The moisture loss resulted in softening after harvesting (Bisen *et al*., 2010). There was a significant difference ($p<0.05$) in PWL within the treatments in both storage conditions (Table II and III). PWL was gradually increased during the storage period in all treatments, where the highest PWL was recorded in the uncoated fruits while the lowest PWL was recorded in the fruits treated with 1% kithul flour in both storage conditions. The coating resulted to reduce the weight loss and respiration rate during the storage period. Temperature controlled storage condition, demonstrated comparatively longer shelf life for all treatments.

B. Change of Peel Colour

Maintenance of the peel colour during the storage period is an important factor which may directly affect the consumer acceptability and the perception of fruit quality. During the storage period, all the fruits completely turned from green to brown colour. The fruits coated with 1% kithul flour turned to yellow colour after 12 days and 35 days in both ambient and cold storage conditions whereas, the uncoated fruits turned

to yellow colour after 4 days and 21 days in both storages respectively (Champa *et al*., 2019).

C. Percentage of Peel Browning

The peel browning was recorded after 8 days of storage in uncoated fruits. And, less than 5% browning was recorded in treated fruits until 12 days of storage under ambient conditions. Under cold storage conditions, browning was recorded at 28 days of storage (DOS) in all treatments. The highest value (30%) was recorded in uncoated fruits whereas, the lowest value (less than 3%) was recorded in treated fruits (1% kithul flour) (Table II and III).

D. Percentage Disease Incidence (PDI)

Disease symptoms were observed only 12 DOS and 28 DOS in both storage conditions. Treatment 2 (1% kithul flour) coated fruits were observed less than 5% PDI up to 42 DOS, and the highest value for PDI was recorded in uncoated fruits as shown in Tables II and III (Ismail Zhang, 2004).

E. Visual Quality Rating (VQR)

There was a significant difference ($p<0.05$) in VQR among the treatments during both storage periods. The fruits treated with 1% kithul flour showed the longest shelf life, it remained green and fresh up to 8 DOS and 28 DOS in both storage conditions (Table II and III) whereas, the untreated fruits remained green and fresh up to 4 DOS and 21 DOS in both storage conditions respectively. The untreated fruits were deteriorated drastically compared to the treated fruits. Therefore, it revealed that the coating acted as a gas and moisture barrier to reduce the loss in appearance during the storage period (Champa, W., Gamage, K., 2020a).

F. Determination of Physiochemical Parameters

There was a significant difference in TSS among the treatments in both storage conditions (Table II and III). In all fruits, TSS content increased slowly and steadily up to 12 days in ambient condition and up to 42 days in cold condition. The maximum TSS content (10.48%) was recorded under ambient storage in 3% kithul flour concentration. The lowest value (7.98%) was recorded in uncoated fruits under cold storage conditions which initiated rotening with the time period. The fruits stored in ambient conditions always obtained a higher TSS value due to high ambient temperature and low relative humidity which may lead to high water loss (Champa, W., Gamage, K., 2020a).

Titratable Acidity and pH were also significantly different ($p<0.05$) among the treatments in both storage conditions. The lowest TA value was recorded in uncoated fruits and the highest value was recorded by 1% kithul flour in both storage conditions, whereas, the maximum pH value was recorded by 1% kithul flour and minimum pH value was recorded by uncoated fruits (T1) in both storage conditions. It revealed that acidity stays the same in treated fruits as coating material acts as an external barrier.

IV. CONCLUSION

The study revealed that newly formulated edible coating using kithul flour (1%) and corn oil has the potential to be used as a coating to fresh limes to extend its shelf life to 12 and 42 days under ambient conditions and cold conditions respectively. When compared with the untreated fruits which showed the shelf life of 8 and 28 days under ambient conditions and cold conditions respectively. Further, it revealed that kithul flour can be utilized as a plant-based edible coating. The coating has no possibility of causing adverse health effects on the consumer.

REFERENCES

Alam, N., Bibi, F., Khan, N., Ahmad, N., Khan, A., Khan, B. T., Rawan, S. (2017). Effect of coating material (corn oil) on the storage life of persimmon fruit. *Pure and Applied Biology (PAB), 6*(1), 363-368.

Rajapaksha, L., Gunathilake, D. M. C. C., Pathirana, S. M. (2021). Reducing post-harvest losses in fruits and vegetables for ensuring food security–Case of Sri Lanka. *MOJ Food Process Technols, 9*(1), 7-16.

Association of Official Agricultural Chemists, Horwitz, W. (2005). Official methods of analysis (Vol. 222). Washington, DC: Association of Official Analytical Chemists, 18th Edition.

Backry, N.F., Isa, M.I.N. and Sarbon, N.M. (2017). Effect of sorbitol at different concentrations on the functional properties of gelatin/carboxymethyl cellulose (CMC)/chitosan composite films. *International Food Research Journal, 24*(4), 1753-1762.

Bisen, A., Pandey, S.K. and Patel, N. (2012). Effect of skin coatings on prolonging shelf life of kagzi lime fruits (Citrus aurantifolia Swingle). *Journal of Food Science and Technology, 49*(6), 753–759.

Champa, W. A. H., Gamage, K. G. N. M. (2020a). Postharvest Dip Application of Putrescine and Salicylic Acid Delayed Postharvest Quality Deterioration and Extended the Storage Life of Lime (Citrus Aurantifolia Swingle) Fruit. *International Journal of Fruit Science, 20*(sup3), S1629-S1638.

Champa, W. A. H., Gunasekera, N., Wilson, W. S., Hewajulige, I. G. N., Weerasinghe, W. M. S. S. K., Kumara, B. A. M. S. (2020b). Postharvest treatment of cinnamon (Cinnamomum zeylanicum) bark oil and hexanal incorporated bio-wax maintains quality and extends marketable life of lime (Citrus aurantifolia swingle). *International Journal of Fruit Science, 20*(1), 76-88.

Champa,W.A.H, Samaradiwakara, D. and Ishwara, J. (2019). Colour chart along with sizing rings for identification of maturity indices of lime. Institute of Postharvest Technology-Anuradhapura.

Dhall, R.K. (2013). Advances in Edible Coatings for Fresh Fruits and Vegetables: A Review. Critical *Reviews in Food Science and Nutrition, 53*(5), 435-450. Ismail, M., Zhang, J. (2004). Post-harvest citrus diseases and their control. *Outlooks on Pest Management, 15*(1), 29.

Jamil, N. E. L. O. F. E. R., Jabeen, R., Khan, M. U. Z. A. F. F. A. R., Riaz, M. U. S. A. R. A. T., Naeem, T. A. Y. Y. I. B. A., Khan, A. Q. S. A., ... Fahmid, S. H. A. G. U. F. T. A. (2015). Quantitative assessment of juice content, citric acid and sugar content in oranges, sweet lime, lemon and grapes available in fresh fruit market of quetta city. *International Journal of Basic Applied Sciences, 15*(1), 21-24.

Perera, S., Rambodagedara, M. and Wijesinghe, R. (2015). Fruit and Vegetable Export Growth, Instaility and Diversification Research Report No.173, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Chart, R. C. (2001). RHS colour chart. London, Royal Horticultural Society.

Wijesinghe, J.A.A.C., Wicramasinghe, I. and Saranandha, K.H. (2015). Kithul Flour (Caryota urens) as a Potential Flour Source for Food Industry. *American Journal of Food Science and Technology, 3*(1), 10-18.

Win, T. O., Srilaong, V., Heyes, J., Kyu, K. L., Kanlayanarat, S. (2006). Effects of different concentrations of 1-MCP on the yellowing of West Indian lime (Citrus aurantifolia, Swingle) fruit. *Postharvest Biology and Technology, 42*(1), 23-3