RESEARCH ARTICLE

Edible Coating from Nontoxic Biomaterials for Extending Shelf Life of Fruits and Vegetables

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ABSTRACT

The present work has been designed to create ecofriendly edible coating from the isolated biomaterials. The biomaterials were extracted from the selected plants such as *Kappaphycusalvarezii* (Doty) Doty ex Silva (Solieriaceae), *Pancratiumtriflorum*Roxb. (Amaryillidaceae), *Terminaliacatapa*L. (Combretaceae) and *Cyanodondactylon*(L.) Pers. (Poaceae). These plants were frequently available biomass and are edible. The extracted biomaterials were mixed together with different ratios to produce the edible coating solution A, B, C, D and E. The colour, odor, pH, bubble, heating resistance, water content and water resistance of the coating solutions were recorded. The coating solution of composition (E) gives the positive result. The produced edible coating solution is colourless and has good stability, quality and shelf life may better alternative to chemical and wax based edible coating solutions. The results of microbiological studies revealed that the edible coating solution has decreased the fungal as well as bacterial contamination and no toxicity. The successfully produced edible coating solutions were applied to selected fruits and vegetables. The following parameters such as shelf life, sensory evaluation, weight loss, pH, shrinkage percentage, shrivelling percentage and decay percentage were analysed at regular intervals and recorded.

Keywords: Biomaterials, biofilm, edible coating, shelf life.

INTRODUCTION

Fruits and vegetables are essential in human's daily diet due to health and nutritional value associated with their intake. However, they are products with a relatively short postharvest life, as long as they are used for consumption, they are living tissues and may undergo physiological and biochemical changes that may have significant physical or pathological manifestations for economic loss [1, 2].

Postharvest treatments with conventional synthetic waxes or chemical fungicides have been used for many years to control postharvest decay and extend shelf life for fruits and vegetables. The continuous application of these treatments has cause health and environmental issues. Considering the growing interest in healthier, safer, more natural and environment-friendly natural coatings have been developed in recent years to avoid the use of synthetic waxes [3]. Hence the use of edible coatings has emerged as an effective and ecofriendly and also alternative to extend their shelf life and protect them from harmful environment [4].

In addition, coatings are able to act as a carrier of many functional ingredients such as antimicrobials, antioxidants, antibrowning agents, nutrients or flavouring and colouring compounds enhancing food stability, quality and safety [5]. The proposed study aims at the production of edible coating film from biomaterials from plants especially from non toxic sea weeds and plants with rich edibility particularly carrageenan, starch, mucilage, cellulose content, gelling agent and antimicrobial properties. Therefore, the present work is designed to create an ecofriendly edible coating from non toxic biomaterials isolated by plants to enhance the shelf life of fruits and vegetables. In order to separate biomaterials from plants the following species has been selected such as *Kappaphycusalvarezii*(Doty) Doty ex Silva (Solieriaceae), *Pancratiumtriflorum*Roxb. (Amaryillidaceae), *Terminaliacatapa*L. (Combretaceae) and *Cyanodondactylon*(L.) Pers. (Poaceae).

MATERIALS AND METHODS

Collection of Plant Materials

The production of edible coating for fruits and vegetables, the following plant materials were selected for the present study such as *Kappaphycusalvarezii*(Doty) Doty ex Silva, *Pancratiumtriflorum*Roxb.,*Terminaliacatappa* L. and *Cynodondactylon* (L.) Per.The selected study plant materials were obtained from various regions of Tamilnadu and Kerala. The seaweed *Kappaphycusalvarezii* were harvested from the coastal regions of Mandapam, Rameshwaram in Tamilnadu. The tubers of *Pancratiumtriflorum* were collected from Karimkulam, Kerala. The *Cynodondactylon*leaves were collected from N.G.M College campus, Pollachi. The essential oil (Clove oil) and badam resins were purchased from the local market. In laboratory, the collected species were washed and cleaned under running tap water to remove salt, sand, dust particles and other impurities. The process was repeated with distilled water. The cleaned plant materials were kept for further studies.

Isolation of Biomaterials

Isolation of Carrageenan[6]

Dried sample of *Kappaphycusalvarezii* seaweeds were cut into small pieces (± 1 cm) and then weighed 50 grams. Samples are soaked with distilled water for 30 minutes. Then, it was extracted using NaOH with the ratio of seaweed to the solvent 1: 20 (g/ml). The extraction was done using a hot plate at 90^0 C. It was filtered using a muslin cloth when it was still hot. The filtered solution was taken in a separate container and 5 % KCl was added to stand for 15 to 20 minutes at room temperature until the gel formation. After the gel formation, they were washed with distilled water to reach the pH of ±7 and filtered using muslin cloth. The isolated carrageenan gel was dried in oven at 60^0 C for 24 hours. The dried powder of carrageenan was weighed and stored for further use.

Identification of Carrageenan
The carrageenan is determined by soluble in water at a temperature of 80^0 C, forming a viscous clear solution and insoluble in ethanol.

Isolation of Starch [7]
The fresh tubers of *Pancratiumtriflorum* were cut into small pieces and the samples were ground with distilled water. The ground slurry was then sieved and filtered using a coarse sieve and muslin cloth. Filtrate was allowed to settle for 2 hours, the resulting starch was washed three times with distilled water and allowed to settle for 21 hours. After 21 hours, supernatant was decanted, the starch (wet) was dewatered and then oven dried at a temperature of 55° C for 4 hours. Finally the dried starch was collected in a container for further use.

Identification of Starch
The iodine test is used to analysis the presence of starch. Add 2 ml of iodine solution in the sample. The colour turned to blue to black confirmed the presence of starch.

Isolation of Cellulose[8]
Cellulose isolation was carried out using the pulping technique consisting of four steps: (1) mild acid hydrolysis with 0.4% H_2SO_4 for one hour, and subsequent washing; (2) chlorination with 3.5% citric acid, stirring the solution in a water bath at 30° C to pH 9.2, washing with distilled water until neutral pH; (3) alkaline extraction with 20 % NaOH under stirring for 1 h, followed by a washing process; (4) bleaching with a solution of 0.5 % citric acid and continuous stirring for 1 hour, and a final wash to neutral pH. Then the material was manually shredded and placed in an oven for 24 hours at 60° C. The material was weighed to determine the total yield of the cellulose.

Identification of Cellulose
The cellulose was confirmed through iodinated zinc chloride solution. A small amount of sample was placed in a watch glass and dispersed with iodinated zinc chloride solution. The violet blue colour confirmed cellulose

Isolation of Mucilage
The shade dried plant materials were soaked with distilled water for 1 hour; fully soaked materials were boiled for 30 minutes and allowed to stand for 15 minutes. Then the material is centrifuged at 8000 rpm for 15 minutes to release mucilage. The supernatant is collected. The yield of isolated mucilage was weighed and stored for further use.

Preparation of Coating Solution
The coating solution was prepared from isolated biomaterials of study plants such as carrageenan, starch, cellulose, mucilage, resin and essential oil (Clove oil). The isolated biomaterials were combined together with different proportion to form a coating solution and to produce final transparent edible coating solution. A known quantity of isolated biomaterials such as carrageenan, mucilage, starch, cellulose, resin and essential oil were added in 100 ml distilled water. The mixture solution was stirred for one hour using magnetic stirrer at room temperature, followed by the solution was heated at 40^0 C for 10 minutes continuous stirring using glass rod. Then the solutions was autoclaved for 121^0 C at > psi for 15 minutes. The final volume of the solutions was kept under room temperature for 1 minute.

Processing of Coating Solution
The edible coating technology was tested for the following fruits and vegetables i.e. *Malusdomestica*Borkh (Apple), *Musa acuminata*Colla (Banana) *Capsicum annuum* L. (Chilly) and *Solanumlycopersicum* L. (Tomato) respectively. The testing samples were selected accordingly uniform size, colour and absence of damage and fungal contamination. The uncoated testing samples (Fruits and vegetables) were used as a control.The testing samples (fruits & vegetables) were capsulated with edible coating solution by dipping process according to Prasad *et al.*, 2018 [9].The testing samples were soaked in 50 % sodium chloride solution for two minutes to remove all contaminants. Further the

samples were submerged in coating solution container for few second. Then the samples were taken out to allow excess coating by drain until the uniform coating formation. Finally the samples were dried under ambient conditions. After drying, samples were stored at room temperature. The observations were performed on both control and coated fruits and vegetables for regular intervals of storage period.

Observations

The following parameters were tested for the present study.

Parameters for Edible Coating Solution

Sensory Evaluation [10]

For sensory evaluation, visual inception of color, odor, bubble and pH were observed.

Heat Resistance Analysis

The heat resistance capacity of prepared coating solutions are identified at 10, 30, 50, 70 and 1000 C temperatures.

Water Content Analysis [11]

Determination of water content was performed by drying method, the following formulae was used as follows.

$$\text{Percentage of Water Content} = \frac{\text{Inital Weight} - \text{Final Weight}}{\text{Inital Weight}} \times 100$$

Water Resistance Analysis [12]

1×1 cm of dried coating film was weighed and soaked for 10 seconds in distilled water. The final weight of the soaked film are weighed. Procedure of soaking and weighing were carried out back until final sample mass will constant.

$$\text{Water resistance (w)} = \frac{W - W_0}{W_0} \times 100$$

Where, W_0 - Initial sample mass, W - Final sample mass.

Microbial Analysis

The antimicrobial activity of coating solution was studied by streak plate method. The microbial inhibition were tested by the following microorganisms such as *Escherichia coli* (MTCC 77), *Staphylococcus aureus* (MTCC 96), *Klebsiellapneumoniae* (MTCC 3384), *Pseudomonas aeruginosa* (MTCC 424) and fungi like *Aspergillusniger* (MTCC 282). The organisms were purchased from PSG Hospitals, Coimbatore, Tamilnadu state in India.100 mm sterile I - petri plates (2-section) were taken and the first section filled with freshly prepared nutrient agar medium and potato dextrose agar medium separately, followed by the second section filled with coating solution. The microbial strains were streaked on the both side of the plate. The inoculated petri plates were kept in incubator at 28^0C for 24 hours. The microbial growth was observed and recoded.

Parameters for Treated Fruits and Vegetables

Shelf - Life Test

The shelf life assessment of testing samples of coated and non-coated fruits and vegetables was assessed by visual inception on daily basis.

Sensory Evaluation [13]

During storage, the sensory evaluation of stored testing samples were performed by a panel of five members on hedonic scale ranging from 0 to 5, where 1 = very bad, 2 = bad, 3 = medium, 4 = good and 5 = excellent. Color, aroma, appearance and overall acceptability were recorded.

Weight Loss [14]

Weight loss of the testing samples was performed for weekly intervals until the end of experiment. The weight loss (WL) percent was determined by using following the formula.

$$WL = \frac{(A - B)}{A} \times 100$$

Where, A - Initial weight. B - Final weight

pH Measurement

The samples were cut into small pieces and homogenized in a grinder. 10 g of grounded samples were suspended in 100 ml of distilled water and then filtered. The pH of the samples was assessed using a pH meter.

Titratable Acidity [15]

The titratable acidity of samples was calculated by titration method. 50 ml of juice samples were titrated with 0.1 N NaOH, few drops of phenolphthalein was used as indicator. The titration done triplate till the concrete reading has been achieved.

$$\text{Percentage of Acidity} = \frac{0.064 \times \text{Normality of NaOH} \times \text{Titre Value}}{\text{Volume of Sample (ml)}} \times 100$$

Fruit Shrivelling Percentage [16]

Fruit Shrivelling Percentage (FSH %) of testing samples was evaluated based on a 4-score scale as: 1- very shrivelling, 2- low shrivelling, 3- normal and 4- very smooth.

Shrinkage Percentage [17]

The length and breadth of fruits and vegetables were measured as an index for shrinkage. The samples were measured by using Verniercalliper weekly interval during the storage period.

$$\text{Shrinkage percentage in terms of length} = \frac{\text{Initial length} - \text{Final length}}{\text{Initial length}} \times 100$$

$$\text{Shrinkage percentage in terms of breadth} = \frac{\text{Initial breadth} - \text{Final breadth}}{\text{Initial breadth}} \times 100$$

Decay Percentage [18]

The testing samples of fruits and vegetables were examined for mold growth during periods of storage. The sample was considered infected when a visible lesion was observed. The decay incidence was expressed as percentage of samples infected for all samples were used for measurement.

$$\text{Decay percentage} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100$$

Statistical Analysis

The collected data of results were analyzed statistically and carried out with the SPSS Software.

RESULTS AND DISCUSSION

Preparation of Edible Coating

The present study for the preparation of edible coating for fruits and vegetables the following biomaterials were extracted *viz.* carrageenan from *Kappaphycusalvarezii* (Doty) Doty ex Silva (Solieriaceae), mucilage and starch from *Pancratiumtriflorum*Roxb. (Amaryillidaceae)cellulose from *Cyanodondactylon*(L.) Pers. (Poaceae) and the resins were obtained from *Terminaliacatapa*L. (Combretaceae) Fig. 1. The current work to produce eco-friendly edible coating from these combinations of biomaterials has a completely new record; previously no work has been published on these formulations. Biomaterials were extracted using different methods. The extracted biomaterials were combined at different ratios to form formulations A, B, C, D, and E. The volume of the final coating solution obtained, colour, pH, odor, heating resistance, water content and water resistance were recorded and tabulated (Table 1, 2 & 3 and Figure 2 to 4). Based on coating ability and quality the formulation E shown positive results, whereas the formulation A, B, C and D are exhibited negative results. Finally the formulation E is selected for the coating process on fruits and vegetables. The edible coating produces has good strength and stability, Therefore the replacement of chemical and synthetic wax based coatings make the basis for sustainable and ecofriendly edible coatings. Likewise many authors have extensively studied ecofriendly edible coatings from plants such as *Aloe vera* gel, neem, lemon grass, rosemary, tulsi, and turmeric. Usually herbs have antimicrobial properties including vitamins, antioxidants and essential minerals [19, 20, and 21].Ginger, essential oil, clove bud oil; turmeric neem extract, mint oil, other essential oil and extracts are also used in edible coating of fruits and vegetables. Herbs are natural source of vitamins, minerals, antioxidants, beneficial for health act as a nutraceutical and medicines [23, 24].

Evaluation of physical and chemical parameters for edible coated fruits and vegetables during storage period

The prepared coating solutions were applied by dibbing method on some selected fresh fruits and vegetables like apple, banana, chilly and tomato respectively. After the coating process it is observed the encapsulated coating looks transparent appearance. During storage period the following physical and chemical parameters were tested.

Sensory Evaluation

The sensory evaluation (color, aroma, appearance and overall acceptability) of the control and coated samples were examined at intervals of three days during the storage period. The edible coating enhances the sensory quality and extends the shelf life of coated samples rather than control samples. Some control samples are deteriorating and completely unacceptable but coated samples remain intact. Thus, the sensory evaluation revealed that the edible coating treated samples score high in hedonic scale than the control samples. At the end of the storage period, panellist members gave high score to edible coated treated samples (Table 4). The coated samples have no significant difference at the end of the storage period. It could be concluded that the maximum score can be related to the minimum water loss from the fruit surface and maintenance of better balance between sugars and acids of fruit juice [25]This study similar to Seehanam*et al*. [26] which said that the coated tangerine fruits showed higher gloss and better visual appearance results as compared with the non - coated fruit.

Weight Loss

The weight losses of coated samples are compared to the control samples during the storage period for all tested fruits and vegetables. Water transfer is restricted by coatings that act as barriers and protect fruit skin, thus delaying dehydration[27]. Thus, the control sample causes changes in morphology as well as fungal and bacterial contamination, while the coated sample has no changes in morphology and the absence of contamination (Table 6). Respiration and transpiration are a major cause of weight loss of fruits and vegetables. Hence the edible coating decreased the respiration and transpiration rate by acting as a semi permeable membrane on the surface of the fruits and vegetables. According to Perez-Gago, Serra and delRio [28], coatings of edible material applied as a thin layer can offer a possibility to extend the shelf life of fresh-cut vegetables by providing a semi permeable barrier for gases and water vapor, reducing, therefore, respiration and water loss and thus avoiding dryness and weight loss.

pH

The pH value of both control and coated test samples were increased gradually during the storage period. The pH value of coated samples was lesser when compared to control samples (Table 6). As the storage time passes, the senescence occurs in fruits during which there will be increase in the pH value [29]. It is also due to a decrease in acidity and an increase in TSS value as the fruits ripen at the storage time [30]. Coating reduces respiratory and metabolic rates, and thereby the lesser utilization of organic acids, reported by Baraiya*et al*. [31].The results showed that the coatings show better control on pH during the entire storage period compared to control samples.

Titratable Acidity

The titratable acidity of uncoated and coated samples was analyzed regularly during the storage period. The titratable acidity level of both control and coated samples were gradually decreased over the storage period. Titratable acidity was higher in coated samples compared with uncoated samples. The reason for fall in acidity level is the utilization of organic acid in the respiration and metabolic process[32] also suggested that the decrease in acidity has been attributed towards the conversion of organic acids into sugars and their further utilization in the metabolic process of the fruit (Table 7).

Shrivelling Percentage

The shrivelling percentage of the control and coated samples were examined at intervals of three days during the storage period based on a 4 - score scale. The control samples showed lowest score compared to coated samples (Table 8).

Shrinkage and Decay percentage

The shrinkage percentage of control and coated fruits and vegetables in terms of length and breadth were observed on weekly intervals. The maximum shrinkage percentage (length) for Banana and Tomato observed in control ranges from 88.56 at 0 day to 84.36 at 14^{th} day of storage and 65.95 at 0 day to 62.17 at 21^{st} day of storage respectively. The shrinkage percentage (length) of coated samples resulted minimum when compared to control; similarly other tested samples also reflected better result for coated samples (Table 9). The shrinkage percentage (breadth) of fruits and vegetables also reflected the minimum value in coated samples than the control (Table 10). It is clearly indicates that the coating biomaterials retard the activity of enzymes responsible for ripening, cell degradation was prevented and help to reduce moisture loss and lesser respiratory gas exchange, hence delay in senescence and lower the shrinkage percentage. Similarly the decay percentage of the coated samples also resulted better than the uncoated control (Table 11).

Microbiological Analysis

Microbiological analyses of edible coating solution were carried out on streak plate method. Two section petri plates were used to fill nutrient agar medium and edible coating solution respectively. After incubation period the streak plates were observed and the microbial growth was noted. Interestingly the result indicates that the first half of nutrient agar medium shows higher microbial population; meanwhile the second half of edible coating solution shows no growth for selected bacterial and fungal strains. It is indicates that the stronger antimicrobial ability of edible coating solution. It may due to the presence of natural antimicrobial compounds in edible coating solution. This edible coating solution has been suggested to as alternatives to synthetic coating ones for preserving fruits and vegetables quality, owing to their effectiveness against spoilage and food borne pathogens. Recently the use of edible coatings as polymeric matrices for the entrapment of natural antimicrobial agents has been investigated as a promising alternative to overcome these limitations by lowering the diffusion of active compounds onto food surfaces and hence maintaining their concentrations at a critical level for microbial growth inhibition over long periods of storage [33]. Moreover, edible coatings may act as a semi permeable barrier providing an additional protection for foods against moisture loss, solute migration, gas exchange, respiration, and oxidative reactions [34].This in agreement with Natalia *et al*. [35] prepared edible antimicrobial coating using plant extracts showed that the extracts of clove, garlic and cinnamon are incorporated in coating to reduce the growth of *Pseudomonas fluorescens* and showed stronger antibacterial activities.

CONCLUSION

In this study, the coated fruits exhibited more shelf life period when compared with the control. The results showed that the edible fruits coating is an eco friendly approach and showed the less microbial growth in room temperature. The present study concluded for edible coating solution used for various fruits and vegetables but the problem is the materials do not resist to over moisture level.

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Table 1. Biomaterials isolation from non-toxic plant raw materials

S.No	Plant name	Biomaterial name	Initial weight (grams)	Final weight (grams)	Percentage of yield (%)	Colour	Texture
1	*Kapphaphycusalverezii*	Carrageenan	5	3.5	70%	White	Powder
2	*Pancratiumtriflorum*	Mucilage	50	20	60%	White	Colloid
3	*Pancratiumtriflorum*	Starch	5	3.5	70%	White	Powder
4	*Cyanodondactylon*	Cellulose	10	0.762	7.62%	White	Powder

Table 2.Formulations of edible coating solutions

S.No	Biomaterials name	Solution A (-)	Solution B (-)	Solution C (-)	Solution D (-)	Solution E (+)
1	Carrageenan	1.5	1.5	1.5	1.0	1.5
2	Mucilage	3.0	3.0	3.0	3.0	3.0
3	Starch	2.0	1.5	0.1	0.5	0.01
4	Cellulose	1.5	1.0	0.5	0.01	0.01
5	Resin	0.2	0.02	0.2	0.02	0.01
6	Essential oil (Clove oil)	0.005	0.005	0.005	0.005	0.01
7	Distilled water (ml)	100	100	100	100	100

+ Positive result, - Negative result

Table 3. Physical properties of edible coating solutions

Properties	Solution A	Solution B	Solution C	Solution D	Solution E
Colour	White	White	White	Colorless	Colorless
Odor	No specific	No specific	No specific	No specific	No specific
Ph	7.3	7.7	7.2	7.9	7.0
Bubble	High	High	Medium	Low	Low
Heating resistance	60	60	60	60	60
Water content	50	35	20	35	15
Water resistance	12.67	17.64	17.64	19.14	20.93

Table 4. Effect of edible coatings on sensory evaluation of fruits and vegetables during storage period

Sample	Treatments	Storage periods (days)							
		0	3	6	9	12	15	18	21
Apple	Control	5	5	4	4	4	3	2	2
	Coated	5	5	5	4	4	4	4	4
Banana	Control	5	3	3	2	1	-	-	-
	Coated	5	5	4	4	4	3	-	-
Chilly	Control	5	5	4	3	3	3	-	-
	Coated	5	5	5	4	4	4	3	3
Tomato	Control	5	5	4	4	4	3	3	2
	Coated	5	5	5	5	5	4	4	4

Hedonic scale ranging from 0 to 5, where 1 = very bad, 2 = bad, 3 = medium, 4 = good and 5 = excellent

Table 5. Effect of edible coatings on weight loss of fruits and vegetables during storage period

Sample	Treatments	Storage period (Weight in grams)			
		0	7	14	21
Apple	Control	140.64±0.27	139.21±0.44	136.2±0.72	120.55±0.54
	Coated	143.52±0.75	140.75±0.58	129.76±0.91	128.19±0.62
Banana	Control	88.56±0.88	87.68±0.91	84.36±1.66	-
	Coated	84.11±0.92	83.7±1.47	81.55±0.97	-
Chilly	Control	12.15±1.27	8.38±0.75	8.12±0.43	-
	Coated	12.54±0.98	12.11±0.95	10.92±0.57	9.2±0.41
Tomato	Control	65.95±0.21	64.14±1.42	65.95±0.62	62.17±0.24
	Coated	60.02±0.34	59.11±0.97	57.56±0.71	56.43±0.39

Mean ± SD

Table 6. Effect of edible coatings on pH of fruits and vegetables during storage period

Sample	Treatments	Storage periods							
		0	3	6	9	12	15	18	21
Apple	Control	4.68±0.14	4.99±0.41	5.00±0.74	5.00±0.92	5.10±0.16	5.14±0.27	5.21±0.44	5.25±1.29
	Coated	4.68±0.25	4.68±0.38	4.97±0.65	5.08±1.21	5.06±0.29	5.11±0.11	5.17±0.75	5.21±0.94
Banana	Control	4.48±0.73	4.48±0.17	4.58±0.52	5.08±0.74	5.26±0.64	-	-	-
	Coated	4.48±0.61	4.50±0.26	4.52±0.47	5.09±0.83	5.29±0.42	-	-	-
Chilly	Control	5.64±0.09	5.50±0.44	5.54±0.66	5.68±0.07	5.71±0.77	5.86±0.45	-	-
	Coated	5.64±0.17	5.39±0.52	5.39±0.72	5.57±0.14	5.69±0.65	5.81±0.71	-	-
Tomato	Control	4.56±0.16	4.36±0.18	4.69±0.61	5.12±0.47	5.07±0.49	5.11±0.94	5.11±0.71	5.26±0.19
	Coated	4.82±0.11	4.90±0.24	5.05±0.58	5.07±0.63	5.11±0.44	5.18±1.28	5.19±0.82	5.20±0.27

Mean ± SD

Table 7. Effect of edible coatings on titratable acidity of fruits and vegetables during storage period

Sample	Treatments	Storage periods							
		0	3	6	9	12	15	18	21
Apple	Control	0.20±0.74	0.18±0.91	0.17±0.46	0.14±0.85	0.13±1.12	0.10±0.41	0.08±0.07	0.07±0.73
	Coated	0.21±0.78	0.21±0.27	0.20±0.24	0.18±0.74	0.16±0.36	0.12±0.41	0.12±0.85	0.10±0.76
Banana	Control	0.23±0.46	0.19±0.09	0.16±0.37	0.11±0.42	0.08±0.78	-	-	-
	Coated	0.22±0.23	0.21±0.17	0.17±0.29	0.14±0.47	0.13±0.11	0.12±0.78	-	-
Chilly	Control	0.27±0.14	0.23±0.84	0.20±0.45	0.18±0.94	0.15±0.65	0.09±0.45	-	-
	Coated	0.27±0.57	0.26±0.42	0.23±0.70	0.19±0.52	0.18±0.23	0.15±0.41	0.13±0.90	0.11±0.54
Tomato	Control	0.31±0.85	0.29±0.46	0.26±0.27	0.21±0.54	0.19±0.76	0.17±0.85	0.13±0.19	0.11±0.57
	Coated	0.32±0.54	0.31±0.86	0.28±091	0.26±0.67	0.25±0.74	0.24±0.82	0.23±0.63	0.21±0.98

Titratable acidity in percentage % Mean ± SD

Table 8. Effect of edible coatings on shrivelling percentage of fruits and vegetables during storage period

Sample	Treatments	Storage periods							
		0	3	6	9	12	15	18	21
Apple	Control	4	4	4	3	3	3	2	2
	Coated	4	4	4	4	4	3	3	3

Banana	**Control**	4	4	4	3	3	-	-	-
	Coated	4	4	4	4	3	2	-	-
Chilly	**Control**	4	4	4	4	3	2	-	-
	Coated	4	4	4	4	4	3	3	3
Tomato	**Control**	4	4	4	4	3	3	2	2
	Coated	4	4	4	4	4	4	3	3

4-score scale as: 1-very shrivelling, 2- low shrivelling, 3- normal and 4- very smooth

Table 9. Effect of edible coatings on shrinkage percentage (length) of fruits and vegetables during storage period

Sample	Treatments	Storage period			
		0	7	14	21
Apple	Control	98.64±0.47	96.21±0.85	94.2±0.92	92.55±0.42
	Coated	98.52±0.76	97.75±1.07	96.76±0.73	96.19±0.84
Banana	Control	88.56±0.99	87.68±0.92	84.36±1.06	-
	Coated	84.11±0.57	83.7±1.22	81.55±0.75	-
Chilly	Control	12.15±1.46	8.38±0.76	8.12±0.48	-
	Coated	12.54±0.31	12.11±0.19	10.92±0.73	9.2±0.42
Tomato	Control	65.95±0.49	64.14±0.45	65.95±0.94	62.17±0.56
	Coated	60.02±0.97	59.11±0.73	57.56±0.57	56.43±0.79

Shrinkage percentage %, Mean ± SD

Table 10. Effect of edible coatings on shrinkage percentage (breadth) of fruits and vegetables during storage period

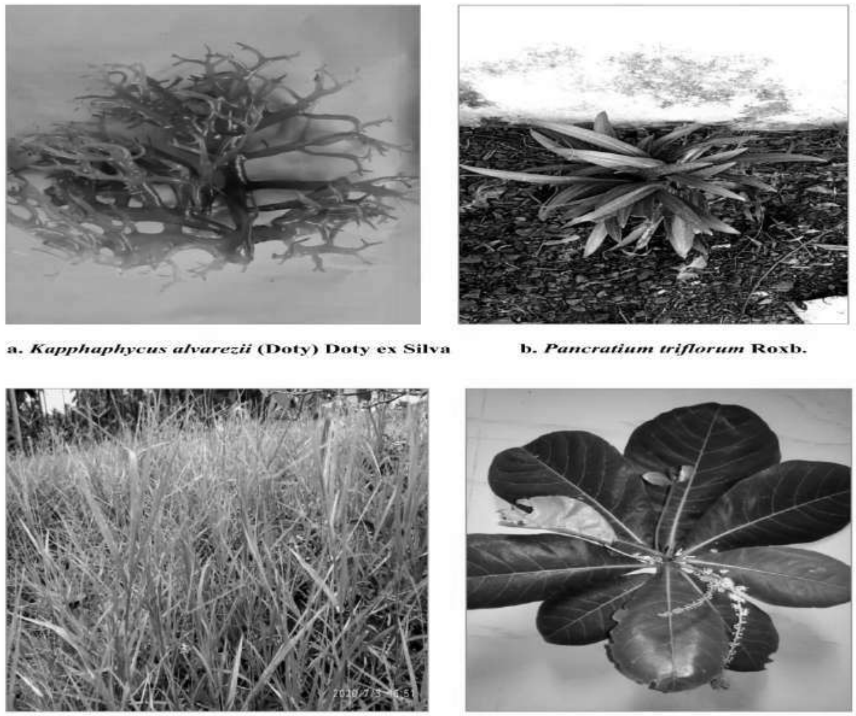
Sample	Treatments	Storage period			
		0	7	14	21
Apple	Control	0	0.93±0.43	2.79±0.1.43	4.65±0.94
	Coated	0	0.47±0.31	1.90±0.82	2.85±1.55
Banana	Control	0	2.54±1.29	5.93±0.46	-
	Coated	0	1.69±1.46	4.23±0.37	-
Chilly	Control	0	4.41±0.93	13.23±0.51	-
	Coated	0	2.77±0.95	4.16±0.97	5.55±0.91
Tomato	Control	0	1.17±0.48	2.94±1.25	5.29±0.42
	Coated	0	0.62±0.29	1.87±0.96	3.75±0.35

Shrinkage percentage %, Mean ± SD

Table 11. Effect of edible coatings on decay percentage of fruits and vegetables during storage period

Sample	Treatments	Initial weight	Final weight	Decay percentage %
Apple	Control	140.64±0.94	120.55±0.88	14.28±0.61
	Coated	143.52±0.41	128.19±1.37	10.68±0.43
Banana	Control	88.56±0.34	84.36±0.48	4.74±0.97
	Coated	84.11±0.49	81.55±0.89	3.04±0.38
Chilly	Control	12.15±0.93	8.12±0.97	33.16±0.46
	Coated	12.54±0.53	9.2±1.14	27.48±0.93
Tomato	Control	65.95±0.83	62.17±0.92	5.73±1.27
	Coated	59.11±0.31	56.43±0.53	4.53±0.91

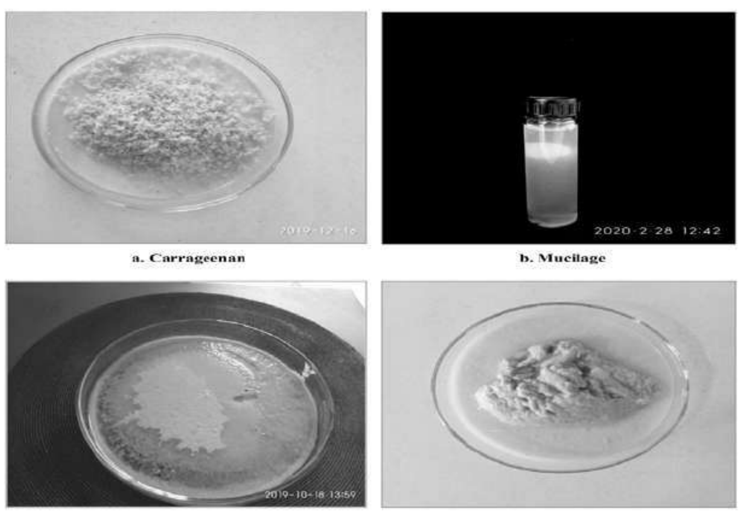
Decay percentage %, Mean ± SD



a. *Kapphaphycus alvarezii* (Doty) Doty ex Silva b. *Pancratium triflorum* Roxb.

c. *Cyanodon dactylon* (L.) Per. d. *Terminalia catapa* L.

Figure 1. Photographs of study plant species



a. Carrageenan b. Mucilage

c. Starch d. Cellulose

Figure 2. Biomaterials isolation process

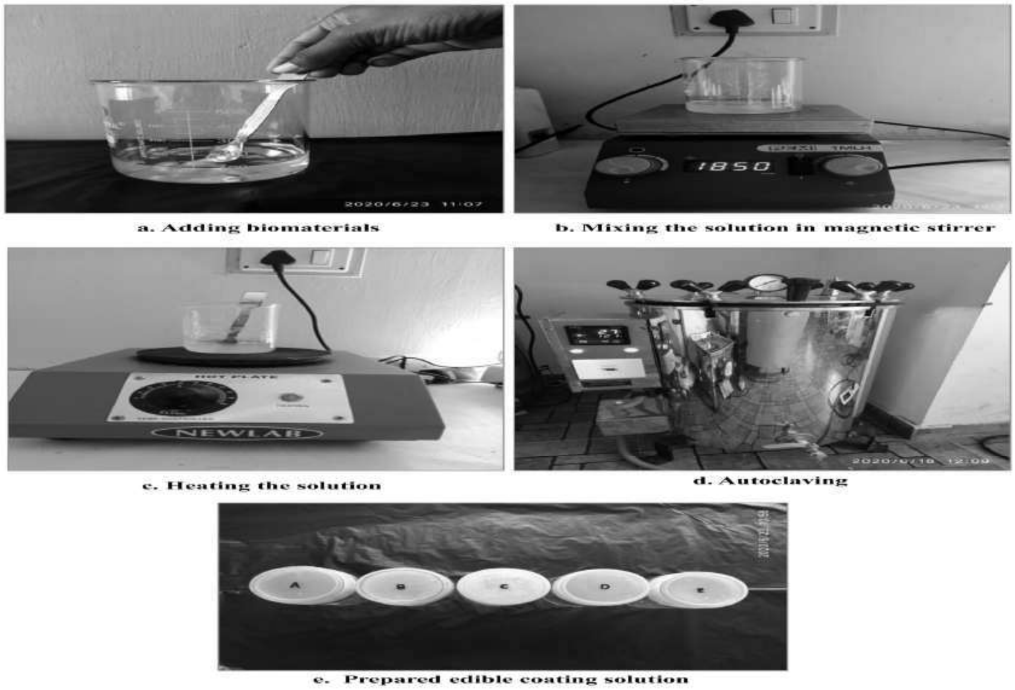


Figure 3. Showing the steps in coating solution preparation

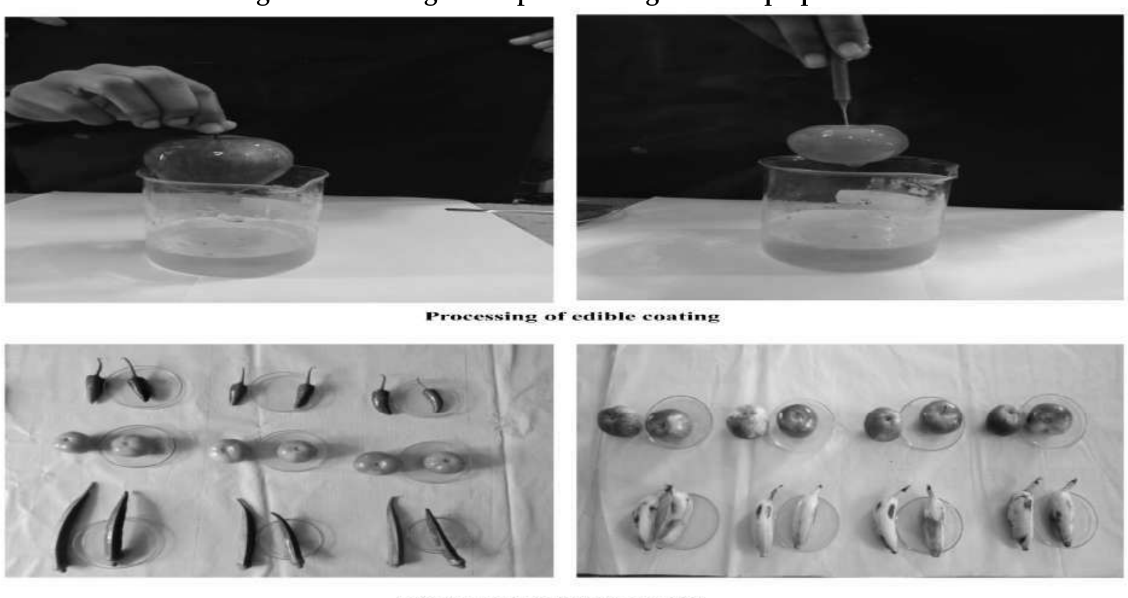


Figure 4. Processing of edible coating on fruits and vegetables

RESEARCH ARTICLE

Effect of Synbiotics on Saliva in Completely Edentulous Patients- a Prospective Study

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ABSTRACT

Xerostomia in older individuals is one of the cause of failure of complete dentures due to lack of retention and stability of dentures. The treatment of choice for such patients is the use of salivary stimulants, topical agents, saliva substitutes, synbiotics and systemic sialogogues and prosthodontically by means of a salivary reservoir incorporated denture. To assess the effect of synbiotics on quantity and pH of saliva in completely edentulous individuals. The study prospectively reviewed pH and quantity of saliva from samples taken from completely edentulous individuals at baseline and after intervention in Control (Group 1) and Study group (Group 2) respectively. Synbiotics did show an increase in quantity of saliva, however, change in quantity and pH of saliva was not statistically significant (P>0.05) The