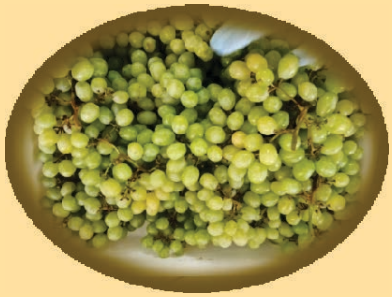
Final Report
of
UGC Sponsored
Major Research Project

ज्ञान-विज्ञान विमुक्तये

"EVALUATION OF BIOSAFE PRODUCTS AS AN ALTERNATE STRATEGY TO IMPROVE THE POSTHARVEST QUALITY AND SHELF LIFE OF SOME PERISHABLE HORTICULTURAL PRODUCE"

[F. No. 43 – 117/2014 (SR) dated 3rd December, 2015]

For the Period from 1st July 2015 to 30th June 2018



Submitted by
Dr. T. V. Ramana Rao
(Principal Investigator)
Department of Biosciences
Sardar Patel University
VALLABH VIDYANAGAR
GUJARAT - 388120

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Annexure VIII

Final Report of the work done on the Major Research Project

1. Project report No. **: 2rd & Final**

2. UGC Reference No. **: *F. No. 43 – 117/2014 (SR) dated 3 Dec. 2015***

3. Period of report **: *From 1st July 2015 to 30th June 2018***

4. Title of research project: ***Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf-life of some perishable horticulture produce***

5. (a) Name of the Principal Investigator **: *Dr. T. V. Ramana Rao***

(b) Deptt. **: *Department of Biosciences***

(c) University/College where work has progressed**:**

Sardar Patel University
VALLABH VIDYANAGAR
Gujarat - 388120

6. Effective date of starting of the project**:** ***1st July 2015 as per the sanction letter dated 3rd Dec. 2015, but the effective date of starting is 1st Jan., 2016***

7. Grant approved and expenditure incurred during the period of the report:

a. Total amount approved **: Rs. 14, 60, 000/-**

b. Total expenditure : **Rs. 9, 37, 323/-**

c. Report of the work done **: Please See Annexure VIII (i)**

i. Brief objective of the project**:** ***Finding suitable biosafe products as an alternate strategy for improvement of postharvest quality and shelf-life of some perishable horticulture produce***

ii. Work done so far and results achieved and publications, if any, resulting from the work (Give details of the papers and names of the journals in which it has been published or accepted for publication)

Please see Annexure VIII(i)

iii. Has the progress been according to original plan of work and towards achieving the objective? If not, state reasons.

Yes, the progress has been almost according to the original plan of work.

iv. Please indicate the difficulties, if any, experienced in implementing the project.

(i) Lack of continuity of Project Fellow

(ii) As sanction letter dated 3rd Dec. 2015 is issued with an effective date of starting from 1st July 2015, the duration of the project got reduced by six months.

v. If project has not been completed, please indicate the approximate time by which it is likely to be completed. A summary of the work done for the period (Annual basis) may please be sent to the Commission on a separate sheet.

Not applicable

vi. If the project has been completed, please enclose a summary of the findings of the study. One bound copy of the final report of work done may also be sent to University Grants Commission.

Project has been completed and the Summary of the findings of the study is being enclosed herewith

Yes, one copy of bound copy of the final report of work done is also being sent.

vii. Any other information which would help in evaluation of work done on the project. At the completion of the project, the first report should indicate the output, such as

(a) Manpower trained:
One after the other, four candidates who worked under this project have been trained.

(b) Ph. D. awarded: - Nil -

(c) Publication of results:
A paper entitled, *"Gum acacia based edible coating combined with physical elicitors maintains nutritional quality and improves postharvest shelf-life of mango" authored by Sayali K. More and T. V. Ramana Rao has been* submitted for its presentation during 106th Session of Indian Science Congress to be held at Jalandhar, Punjab during Jan., 3 – 7, 2019.

(d) other impact, if any :

- Nil -

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

REGISTRAR/PRINCIPAL

(Seal)

Annexure – VIII (i)

7 (c). Report of the work done

In India, there is a vast scope for growing fruit and vegetables throughout the year in one or other part of the country because the climatic conditions are highly suitable for growing various types of fruits and vegetables. Thus now India ranks second in fruits and vegetables production in the world, after China. As per National Horticulture Database (2017) published by National Horticulture Board, during 2016-17, India produced 92.8 million tonnes of fruits and 175 million tonnes of vegetables. Fruit production is increasing worldwide also. Fruits and vegetables are available in surplus only in the certain seasons and availability in different regions. One of the limiting factors that influence their economic and nutritional value is the relatively short ripening period and reduced post-harvest life. Fruit and vegetables are of highly nutritional value. They are cheapest and food supplied in fresh or processed or preserved form throughout the year for human consumption.

However, the quality of fruit and vegetables changes when going through the supply chain, either for good or for worse. These changes can be physiological, biochemical and microbiological. The activities in the supply chain are therefore all to be directed towards attaining or preserving the optimal quality when the product reaches the consumer. Quality concerns food safety but also smell, taste, texture, nutritional value, etc. it is of course self evident that pre-harvest production practices may seriously affect postharvest quality and results in the rejection or downgrading of produce at the point of sale. It can in fact be difficult to make a distinction between the losses associated with poor farming conditions and postharvest losses. Quality starts in the field or orchard and additional environmental factors such as soil type, temperature, frost, and rainy weather at harvest can have adverse effects on storage life and quality (Gogh, 2013). In general, the postharvest system includes all stages in the chain where the activity is intended to add value to the final product. Once harvested, fruits have a limited postharvest life because they no longer receive water or nutrition from the plant. Likewise, a wide spectrum of biochemical changes such as increased respiration, chlorophyll degradation, biosynthesis of carotenoids, anthocyanins, essential oils, and flavor and aroma components, increased activity of cell wall degrading enzymes, and a transient increase in

ethylene production are some of the major changes involved during fruit ripening. Naturally occurring senescence in produce leads to a softening of the tissues and often a loss of performed essential substances. These changes in the fruit or vegetables lead to the senescence processes which make it less desirable to consumers. According to Purky (2011), one third of the food produced is lost or wasted globally among which postharvest losses are a major one.

According to a study carried out by ASSOCHAM, India incurs post-harvest fruits and vegetable losses worth over Rs 2 lakh crore each year largely owing to the absence of food processing units, modern cold storage facilities and callous attitude towards tackling the grave issue of post-harvest losses (Fig. 1)**.**

Figure 1: THE ECONOMIC TIMES | Agriculture

India incurs Rs 2 trillion/year post harvest loss of fruits and vegetables

PTI Sep 1, 2013, 01.40 PM IST

(India incurs Rs 2 trillion/year……..)

Postharvest loss is described as "losses between harvest and onward supply of produce to markets and equates broadly with waste in the food supply chain" (Parfit and Barthel, 2011). When 20% of a harvest is lost, 20% of the land used to grow it and 20% of water required is also been lost along with the human labour, seeds, fertilizer and every investment in the crop.

Moreover, these losses translate not only into human hunger and financial loss to farmers, but also into tremendous environment waste. Reducing losses could, therefore, have an "immediate and significant" impact on livelihoods and food security (Collins, 2009; Parfitt et al, 2010). Food security is on the top among one of the political and scientific agenda's. In recent years, escalating food prices have highlighted the supply of food being inadequate for many in developing countries. On top of this, food losses and wastage have an additional perverse effect, not only from the perspective of resources productivity and overall sustainability of the global food system, but also from the simple fact that reducing waste will improve food availability. Thus food losses have impact on food security (Gustavsson et al., 2011; Escalar and Teng, 2011). The value addition is a process of adding value to a food commodity which may include any unit operation during product development from simple washing to complex manufacturing process. Adding valued features to products is a common method used to markest a product or food material, since it can help increase sales and profit (Parveen et al., 2012).

In peak season due to improper handling practices, marketing, storage problems, around 20-25% fruit and vegetable are spoilt in various stages. For every one percent reduction in loss will save 5 million tons of fruit and vegetable per year. Therefore, proper handling, packaging, transportation and storage reduce the post harvest losses of fruit and vegetables. Fruit and vegetable are living commodities as they respire. Hence, proper post harvest management is necessary.

Some of the major causes of postharvest losses are listed below.

Major causes of postharvest food losses (PHL)

	Main categories						
	Infrastructure:	**Marketing:**	**Technology:**	**Finance:**	**Refrigeration:**	**Organisation:**	**Inputs:**
Sub-categories	• Storage • Road quality • Connectivity • Distance • Energy	• Market information • Chain length • Pricing • Standards in quality & services • Facilities market outlets • Hygiene • Labeling & branding	• Packaging • Grading, sorting • Quality control • Product handling (PH) • Processing	• Access to credit • Investment analysis • Economies of scale • Production coat	• Transport climate control • Cold chain • Climate	• Relations in business • Available services • Education/R & D • Structure/Type of organization • Social/Cultural issues	• Seeds • Crop protection • Water

As a result, several postharvest technologies have been developed to control food contamination and improve nutritional quality. The goals of postharvest research and extension are to maintain quality and safety and minimize losses of horticultural crops and their products between productions and consumption. Reduction of postharvest losses increases food availability to the growing human population decrease the area needed for production and conserves natural resources. Most horticulturists are involved to some extent in some aspects of postharvest horticulture, al least as consumers desiring fruit and vegetables with good flavor and nutritional quality and ornamentals with attractive appearance and long post production life.

Today various methods are used to keep our food protected e.g. Modified Atmosphere Packaging (MAP), Controlled Atmosphere (CA), edible coatings, physical and chemical treatments etc. Among those techniques, there is a mounting interest in eco-friendly edible coatings due to factors such as environmental concerns, new storage

techniques and markets development for underutilized agricultural commodities. Edible coatings are traditionally used to improve food appearance and conservation. They act as barrier during processing, handling and storage, and do not solely retard food deterioration enhancing its quality, but are safe due to natural biocide activity, or to the incorporation of antimicrobial compounds (Martinez et al. 2006).

The concept of using edible coatings to extend shelf life of fresh and minimally processed produce and protect them from harmful environment effects has been emphasized based on the need for high quality and the demand for minimal food processing and storage technologies. By regulating the transfer of moisture, oxygen, carbon dioxide, aroma, and taste compounds in a food system, edible coatings have demonstrated the capability of improving food quality and prolonging shelf life of fresh produce (Lin and Zhao, 2007). Besides, one of the major, advantages of edible coatings is that several active ingredients can be incorporated into the polymer matrix and consumed with the food, thus enhancing safety or even nutritional and sensory attributes. Consumption of whole food, such as fruits and vegetables, is strongly associated with reduced risk of chronic diseases. It is now believed that dietary supplements do not have the same health benefits as a diet rich in fruit and vegetables because, taken alone, the individual antioxidants studied in clinical trials do not appear to have consistent preventive effects. So to overcome such setbacks, postharvest techniques can be further developed to enhance the nutritional values directly in the fruits and vegetables for direct consumption.

A variety of edible coatings materials are used in the postharvest treatment e.g. Carbohydrate based coatings like chitosan, carageenan, CMC, Arabic gum, xanthan gum; Protein based coatings like gelatin, sodium caseinate, zein, wheat gluten; Lipid based coatings like paraffin wax, candellila wax, shellac etc and emulsion or composite coatings (Lin and Zhao, 2007). Recent emphasis and interest in the development of edible coatings have been focused on composite or bilayer coatings, such as integrating proteins, polysaccharides, and/or lipids together for improving functionality of the coatings. It is required that the eduble coating must adhere to the food, but most cases it does not stick to the packaging material. To overcome the poor mechanical strength of sole compounds, they can be used in the combination with hydrophilic materials by means of the formation

of an emulsion with hydrocolloid layer. In composite films and coatings, the polysaccharide or protein is said to provide the film ingredity and entraps the lipid component, and the lipid component imparts the moisture-barrier property (Krochta, 1997).

The addition of plasticizers may help to increase flexibility of the coatings, decreasing brittleness, by reducing the internal hydrogen bonds between polymer chains and increasing intermolecular spaces and due to their hydrophilic nature, the incorporation of a lipid substance to the coating mix may be necessary in order to improve water vapor barrier properties (Sothornvit & Krochta, 2000).

In addition, Edible coatings are an excellent vehicle which can carry functional ingredients such as antioxidants, antimicrobials, nutraceuticals, texture enhancers, antibrowing agents and flavors to further enhance food stability, quality, functionality and safety (Lin and Zhao, 2007). Incorporation of antioxidants and nutraceuticals in the edible coatings has been proved in improving the health beneficial properties of fruits. In addition, coatings can also act as carriers for fungicides or growth regulators and improve fruit gloss (Maria et al., 2011). Use of antimicrobial edible coatings has been expanded which may provide increased inhibitory effects against spoilage and pathogenic bacteria by maintaining effective concentrations of the active compounds on the food surfaces.

Recently, due to health awareness, public have become interested in foods that support and promote health. Hence, to meet this aspiration, the use of postharvest elicitors that can promote the levels of Phytochemicals in postharvest crops has become an area of key interest (Huyskens-Keil and Schreiner, 2004). Postharvest elicitors are defined as physical or chemical elicitors, which may induce the synthesis of phytochemicals in plants. Phytochemicals reveal health promoting impacts as antioxidants, blood pressure or blood sugar influencing sunbstances or agents with anticarcinogenic, immunity supporting, antibacterial, antifungal, antiviral, cholesterol lowering, antithrombotic or anti-inflammatory effects (Schreiner and Huyskens-Kell., 2006). In recent years, consumer interest in the health enhancement role of specific foods or physically active food components, so-called nutraceuticals or function foods, has exploded (Hasler, 1998).

So far, there is grand possible for the application and success of this postharvest technology in extending the shelf-life and maintain the quality of fresh fruit. However, with growing consumer awareness in food having health promoting quality, attention has been shifted from quality maintenance to quality enhancement of the food. Therefore, to obtain the food enriched with health promoting nutritional values, further effort is needed to find the optimum formulation of natural and biodegradable ingredients which leads to a longer shelf life with enhanced nutritional quality of fresh fruits and vegetables.

Rationale for taking up the project

Fruits and vegetables are of highly perishable nature in short span and therefore their postharvest losses are to be reduced by enhancing the shelf life. Hand by hand, the improvement of nutraceutical quality of fruits and vegetables also should be focused.

Relevance to state priorities

Most of the indigenous fruits are edible and they can play an important role in the diets of rural communities but information on sustainability, transformation and value addition of these fruits is scare. Therefore, value addition of these fruits by processing into different food products on the basis of community needs is required and for achieving this, giving training to rural communities on value addition is necessary in India especially Gujarat. The training knowledge and skills provided will help communities to improve livelihood by contributing to job creation, income generation and household food security. Moreover, the reduction in postharvest losses of fruits and vegetables by value addition will be helpful in improving or retaining the economy of the agriculture sector in Gujarat.

CHALLENGES AND CONSTRAINT

One of the most critical challenges is orienting output from current project in production and marketing to the consumer, both internally and externally. Consumers demand a diverse range of high quality safe products. Product diversification through food processing, new product development, improved quality and safely supported by market studies is one of the ways through which to create new products and expand

market opportunities. The integration of postharvest research with the food processing industry is quite intricate as new product development like production of value added fruits and vegetables, food safety and quality in the management of food supply chains increases competitiveness and contribute significantly to the establishment of sustainable food supply chains that are consumer oriented and therefore competitive.

During commercialization of value added fruits and vegetables the major constraints are inadequate technical skills, inadequate supply of proper packaging, poor market analysis. There is generally little effort to analyze market requirement and consumer expectations. As a consequence, production is not market oriented and customer satisfactory. Therefore access to appropriate technologies, skills and market information remains the most critical challenge for small scale research in India particularly Gujarat.

Methodology:

The Methodology proposed for the present study:

Collection of the sample

The selected fruit were procured at their commercial mature stage and they were coated with suitable formulations of natural extracts. The effect of the coatings on quality and shelf-life of the fruit selected for the current study was assessed by incorporating the physicochemical and biochemical characteristics described herein below:

- Weight loss percentage, decay percentage and shelf life of coated and uncoated fresh fruit samples were carried out according to the AOAC (1994).
- Measurement of the total soluble solids (TSS), and pH were performed from fresh fruits as well as juices by following the methods of Mazumdar & Majumder (2003).
- The total sugars content was determined by following the anthrone method (Thimmaiah, 1999).
- The quantitative analysis of total carotenoids was carried out as per the methods described by Wang et al. (2005).

- Total anthocyanin and total flavonoid content were measured by adopting the methodology of Lee & Francis (1972).
- Quantitative analysis of total phenolic (TP) content and ascorbic acid (AA) content were carried out as per the method of Vinson et al (2001) and Jagata & Dani (1982), respectively. Extraction estimation of proteins were carried out as per the method of Bradford (1976).
- Antioxidant capacity assay by using diphenyl picryl hydrazyl (DPPH) was performed by following the method of Narwal (2009).
- Visual quality analysis was performed by following the methodology of Rocha et al. (2007).
- **Cell wall softening related enzymes:** Polygalacturonase (PG) and Cellulase were assayed according to the procedures described by Srivastava and Dwivedi (2000), Pectin Methyl Esterase (PME) (From fruit as well as juice) was assayed by using the methodology of Hungermann and Austin (1986),

1. Custard apple (*Annona squamosa* L.) var. Balanagar

Introduction:

Custard apple (*Annona squamosa* Linn.), popularly known sugar apple, is one of the most important fruits due to its nutritional and medicinal values, but custard apple fruits are very delicate and highly perishable. In India, sugar apple is grown in an area of 21.77 thousands hectare among the total area under fruit crops with an annual production of 165.15 million tones. As it is climacteric fruit, the ripening related biochemical changes occur in it at a faster rate. As a result of the quick postharvest changes the mature fruits ripen quickly and become excessively soft within 2 to 3 days. Therefore they become unfit for consumption. Post harvest handling losses of custard apple is reported to be 13-25%, while transportation loss is reported to be between 3 to 6%. According to the information available from National Horticulture Board (NHB), the production of custard apple in Gujarat for the year 55.04 tonnes, its share (%) is 24.10. The reported diseases of custard apple mainly due to fruit rot – the fruit infection takes place both from blossom end as well as stem end side as dry dark broom spots (ICAR Horticulture).

Therefore, there is a great need to increase the shelf life of custard apple fruit and that kind of research output would certainly benefit the growers and also subsequently consumers. Among many of postharvest treatments, fruit coating is an alternate strategy as they not only improve external appearance, but also modify the internal atmosphere of fruits ((Saftner, 1999). These fruit coatings are gaining importance in improving the post harvest shelf life, especially in reducing the moisture loss and maintaining firmness (Farooqhi et al., 1988); Chauhan et al., 2005; Patel et al., 2011). Also these coatings make good oxygen and lipid barriers at low to intermediate RH, because the polymers can effectively make hydrogen bonds. The present investigation was planned with the hypothesis that deterioration in custard apple fruits is triggered from the sites of weak attachments at the junctions of cohering carpels. Several naturally available sources, which are edible and produce a fine coating, have the capacity to retard the rate of ripening. Keeping the above facts in view, an experiment was planned and executed.

Guar gum is a galactomannan rich flour, water soluble polysaccharide obtained from the leguminous Indian cluster bean *Cyamopsis tetragonoloba* (L.) Taub. The backbone of this hydrocolloid is a linear chain of D-mannopyranose units connected to

each other by β-1,4-bonds linked to galactose residues by 1,6- bonds forming short side-branches (Roberts, 2011; Moser et al., 2013; Heyman et al., 2014). Guar gum is one of the most important thickeners and is a versatile material for many food applications due to its different physicochemical properties as well as its high availability, low cost, and biodegradability. This galactomannan has similar properties as carrageenan, alginate, xanthan gum, and gum arabic as an edible coating but guar gum has the advantage of being cheaper than all the others.

Collection of fruit and application of treatments

The custard apple fruits of 'Balanagar' variety (9 Kg) were procured at their commercial mature stage from Anand Agriculture University, Anand. These fruits were then disinfected with 0.2% sodium hypochlorite solution for 5 minutes. The fruit of custard apple were distributed into five groups with each group consisting of 8 fruits. The following five treatments were selected for the custard apple: (1) **T1** – 0.5% Guar gum; (2) **T2** – 1% Guar gum; (3) **T3** – 0.5% Guar gum + 0.1% clove oil; (4) **T4** – 1% Guar gum + 0.1% clove oil; (5) **T5** – Control. The dipping method was used for 5 minutes followed by air drying and stored at 24°C±2°C. The fruits samples were then subjected to physic-chemical analysis and biochemical analyses at a regular interval of 3 days.

Results:

Effect on weight loss percentage (WLP)

The results regarding the WLP change in coated and uncoated custard apple during storage time are represented in Table 1.1 and Figure 1.1. Guar gum application on custard apple fruit was not found effective in reducing the WLP during 8 days of storage. The result showed that WLP increasing throughout the keeping of custard apple at 24°C in both treated and untreated samples. This can be explained by the fact that the guar gum could not form a layer in the furrows region properly and these are site of higher water loss.

Table 1.1: Effect of guar gum based edible coating on weight loss percentage of custard apple.

	Weight loss percentage (%)				
Treatments	Storage period (Days)				
	0	2	4	6	8
T1	0	4.9723757	9.9447514	15.469613	19.889503
T2	0	5.5172414	11.034483	15.862069	ND
T3	0	5.8441558	11.688312	16.883117	21.428571
T4	0	5.5555556	10.416667	ND	ND
C	0	5.027933	10.055866	14.52514	ND

Table 1.2: Effect of guar gum based edible coating on TSS and pH of custard apple.

Treatments	**Storage period (Days)**				
	Total Soluble Solids				
	0	2	4	6	8
T1	8.0±0.0	10±0.0	9.0±0.0	16.0±0.0	20.0±1.0
T2	8.0±0.0	13±1.0	7.0±0.0	19.0±0.0	19.0±1.0
T3	8.0±0.0	8.33±0.58	19.0±0.0	19.33±0.58	11.0±0.0
T4	8.0±0.0	9.33±0.58	9.33±0.58	19.33±0.58	17.0±0.0
C	8.0±0.0	12.67±0.58	17.0±0.0	19.0±0.0	25.67±0.58
	pH				
	0	2	4	6	8
T1	6.12±0.03	6.28±0.01	6.51±0.01	5.39±0.02	4.24±0.01
T2	6.12±0.03	6.18±0.005	5.63±0.01	5.54±0.012	4.76±0.06
T3	6.12±0.03	6.45±0.02	5.65±0.01	5.56±0.01	4.56±0.01
T4	6.12±0.03	6.32±0.005	6.5±0.01	5.39±0.06	4.39±0.015
C	6.12±0.03	5.84±0.03	5.67±0.006	5.44±0.06	4.44±0.01

Effect on TSS and pH

Significant difference was observed in TSS (Table 1.2 and Figure 1.1) for the coated and uncoated custard apple during storage period of 8 days. At initial stage of storage, TSS was 8.0±0.0°Brix, which increased gradually in uncoated samples with advancement in storage time and reached to the highest level (25.67±0.58°Brix) at the end of storage time. However, the coated samples showed delayed increase in TSS content during 8 days of storage period at 24°C. The decrease in the uncoated samples was continued with the advance of storage time.

Initially, pH value was 6.11±0.03, which declined to 4.44±0.01 on 8th day of storage (Table 1.2 and Figure 1.1). This diminishing pattern was at slower rate in coated custard apple as compared to uncoated samples. T1 and T4 coated custard apple set maintained pH value up to 4 days of storage and thereafter reduced to ~4.3 by end of storage time, while T2 and T3 maintained pH value up to 2 days of storage and then declined at the end of storage. The decrease of pH with advance of storage period might be due to the growth of microorganism or carbon dioxide accumulation in packages.

Effect on Total sugars

Sugars content in fruit can be affected by respiration which consumes sugars as the first substrates (Rivera-López et al., 2005). At 0 day of storage, total sugar present in custard apple was 72.65±8.20 mg/g. As represented in Table 1.3 and Figure 1.1, the decreasing pattern of total sugars was noticed during 8 days of storage period. Both coated and uncoated custard apple showed reduction in total sugars on 2nd day of storage. The highest decline in TS was found in T1 set (~76%) and least decline in T4 samples (~38%) on 2nd day of storage. Thereafter, the rise in TS was observed in T1 and control samples, while it was fluctuating in T2 and T4 samples but less change in T3 sample up to 6 days of storage. The overall result showed that TS declined at the end of storage period in all coated and uncoated samples, indicating that both treated and non treated custard apples retain TS content up to 6 days of storage.

Effect on Ascorbic acid

The concentration of ascorbic acid in custard apple noted initially was 65.45±0.87 mg/g FW. During the storage period of 8 days, there was an abrupt decline in ascorbic acid on 2nd day of storage in all the coated and uncoated custard apple. However, thereafter low level of ascorbic acid concentration was maintained till the end of storage time. This loss in custard apple may be the result of consumption of ascorbic acid due to the respiration during their storage.

Effect on Total phenol content

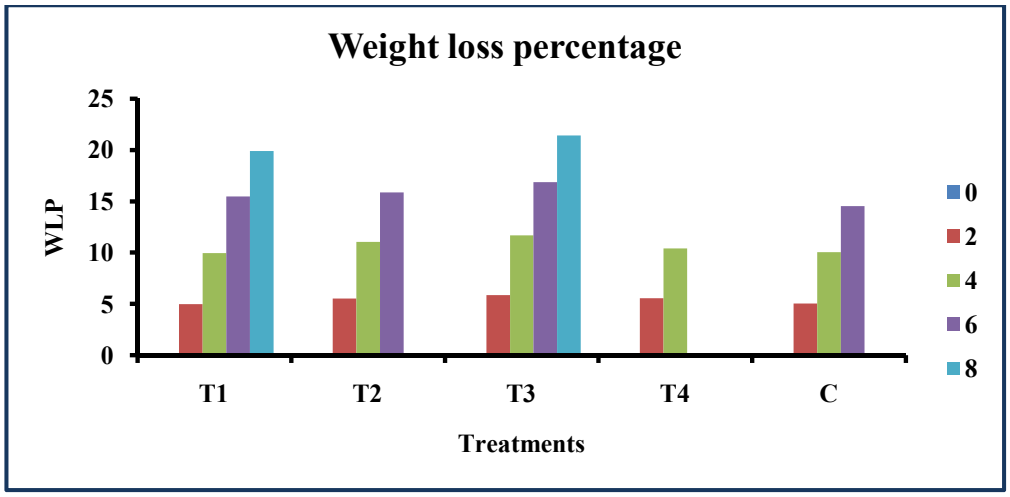
The result regarding the change in total phenol content of coated and uncoated custard apple is represented in Table Fig. In fresh custard apple, the amount of total

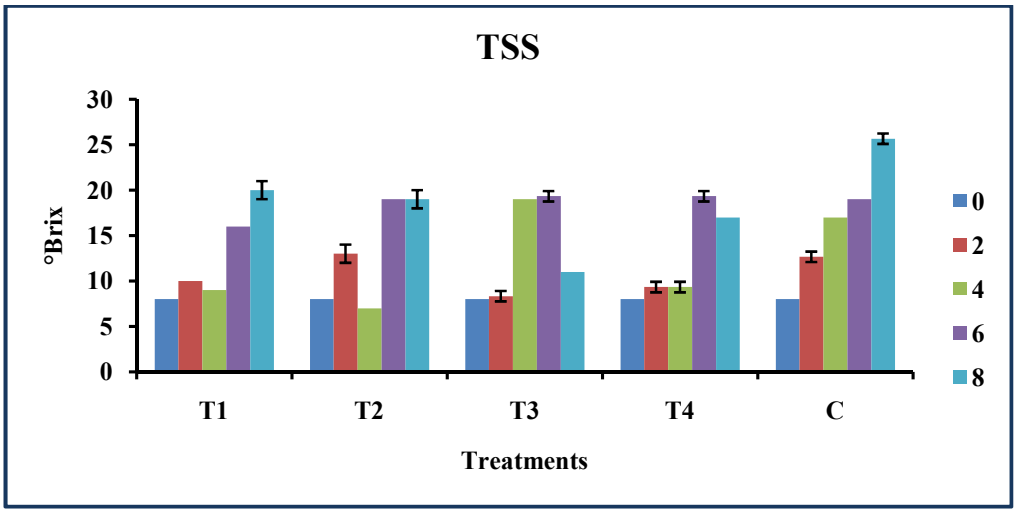
phenol was measured 1.34±0.04 mg/g GAE. The uncoated custard apple showed 12% reduction in TP content relative to its initial value on 4th day of storage and thereafter increased from 1.18±0.02 mg/g GAE on 4th day to 1.91±0.09 mg/g GAE at the end of storage time. The changing pattern of total phenol content was varying depending upon the applied treatments. Custard apple treated with 0.5% guar gum showed two fold rises in the amount of total phenol content on 2nd day of storage period, while it was declined to 0.98±0.03 mg/g GAE and 1.11±0.06 mg/g GAE in T2 and T4 samples on 2nd day of storage. The least change in TP content was noted for custard apple treated with 0.5% guar gum enriched with 0.1% clove oil up to 6 days of storage period but it abruptly increased reaching to the highest amount i.e. 2.55±0.066 mg/g GAE on 8th day of storage. However, custard apple coated with 1% guar gum alone or in combination with 0.1% clove oil exhibited fluctuating trend from 2nd day onwards with increased value on 4th day, reduced on 6th day and again enhanced on 8th day of storage.

Table 1.3 Effect of guar gum based edible coating on TS, ascorbic acid and total phenol content of custard apple.

	Storage period (Days)				
Treatments	**Total sugars**				
	0	2	4	6	8
T1	72.65±8.20	16.82±1.31	36.21±1.93	43.64±1.17	38.34±4.45
T2	72.65±8.20	39.91±4.77	30.09±2.60	45.91±2.24	27.88±1.18
T3	72.65±8.20	42.49±4.42	45.71±2.55	41.55±5.71	9.88±1.16
T4	72.65±8.20	44.71±5.03	58.71±2.05	48.04±1.02	24.50±2.29
C	72.65±8.20	40.25±5.42	50.22±0.14	55.53±0.23	38.21±2.87
	Ascorbic acid				
	0	2	4	6	8
T1	65.45±0.87	26.1±0.65	12.48±0.31	8.8±0.23	14.95±0.46
T2	65.45±0.87	11.1±0.15	16.67±1.01	10.1±1.76	13.86±0.87
T3	65.45±0.87	4.35±0.15	13.47±1.33	8.9±0.88	17.71±0.57
T4	65.45±0.87	10.0±0.23	7.87±0.61	8.65±1.05	12.71±0.29
C	65.45±0.87	18.6±2.60	13.2±1.77	12.65±1.99	22.43±0.89
	Total phenol content				
	0	2	4	6	8
T1	1.34±0.04	2.66±0.06	1.17±0.05	1.82±0.03	1.00±0.15
T2	1.34±0.04	0.97±0.03	1.68±0.05	1.16±0.06	1.40±0.08
T3	1.34±0.04	1.3±0.02	1.43±0.17	1.35±0.07	2.55±0.07
T4	1.34±0.04	1.11±0.06	1.59±0.01	1.00±0.09	1.59±0.07
C	1.34±0.04	1.36±0.05	1.18±0.02	1.31±0.02	1.91±0.09

Figure 1.1: Effect of guar gum based edible coating on weight loss percentage (WLP), TSS and pH of custard apple.





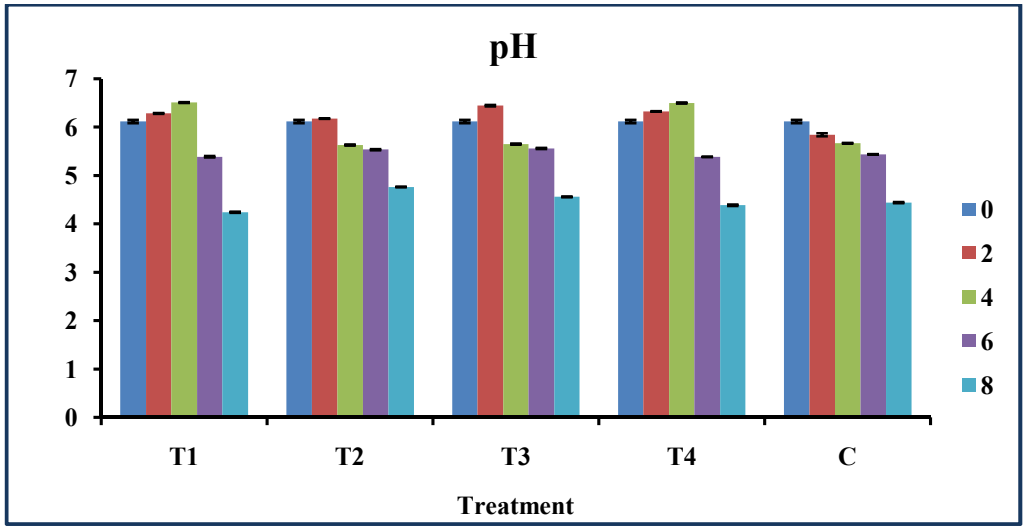
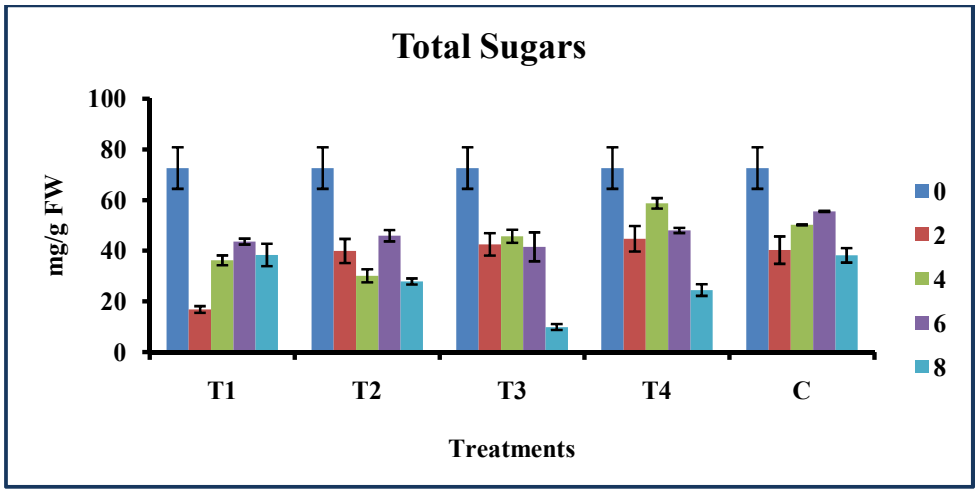
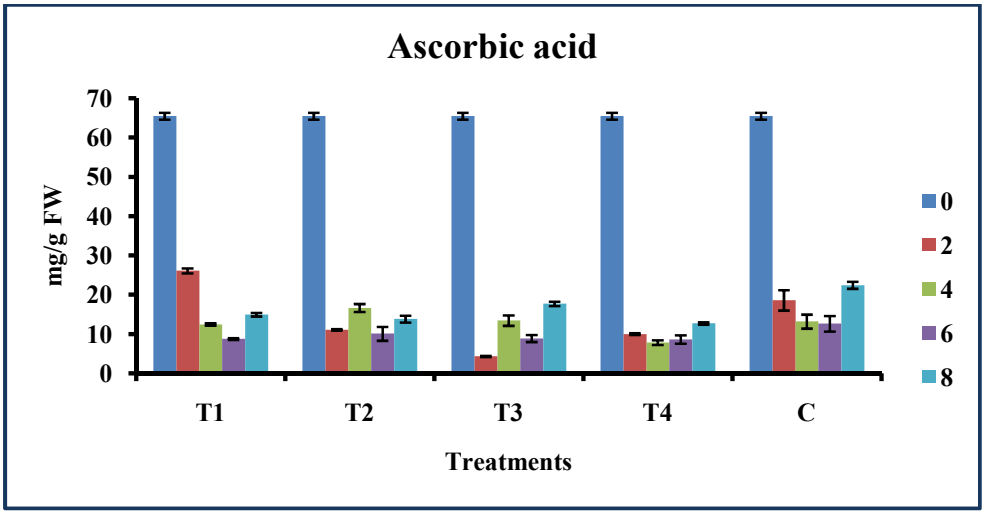


Figure 1.2: Effect of guar gum based edible coating on total sugars, ascorbic acid and total phenol content of custard apple.





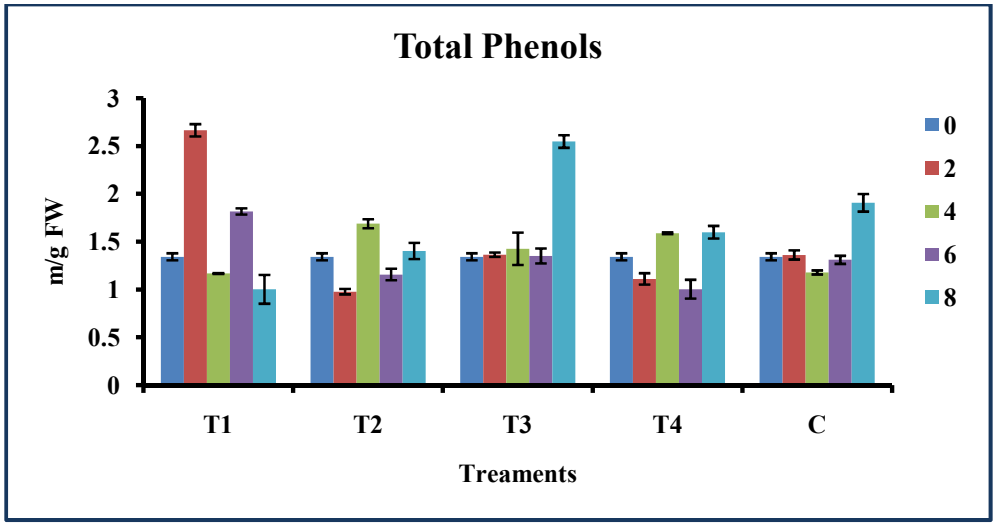


PLATE 1.1

A – Custard apple farm, Anand Agriculture University, Anand.

B – Custard apple fruit kept in 0.2% sodium hypochlorite solution.

C – 0.5% Guar gum solution

D – 1% Guar gum solution

E – 1% Guar gum solution + 0.1% Clove oil

F – Custard apple kept for air drying after surface disinfection

G – Custard apple kept for air drying after edible coating treatments

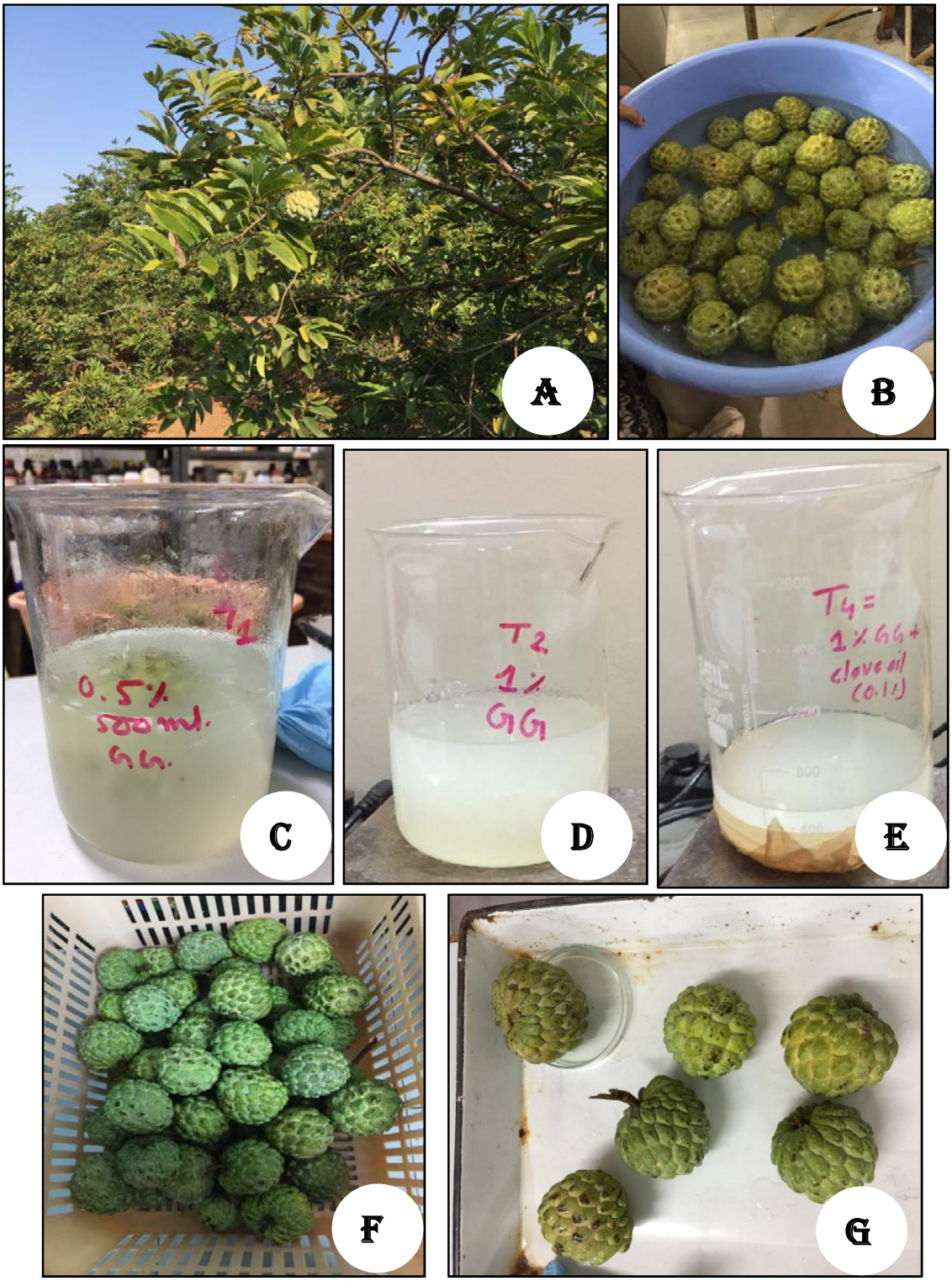


PLATE 1.1

PLATE 1.2

Effect of guar gum based edible coating on visual quality of custard apple on 2nd day of storage

T1 – 0.5% Guar gum

T2 – 1% Guar gum

T3 – 0.5% Guar gum + 0.1% clove oil

T4 – 1% Guar gum + 0.1% clove oil

C – Control

PLATE 1.2

PLATE 1.3

Effect of guar gum based edible coating on visual quality of custard apple on 4th day of storage

T1 – 0.5% Guar gum

T2 –1% Guar gum

T3 – 0.5% Guar gum + 0.1% clove oil

T4 – 1% Guar gum + 0.1% clove oil

C - Control

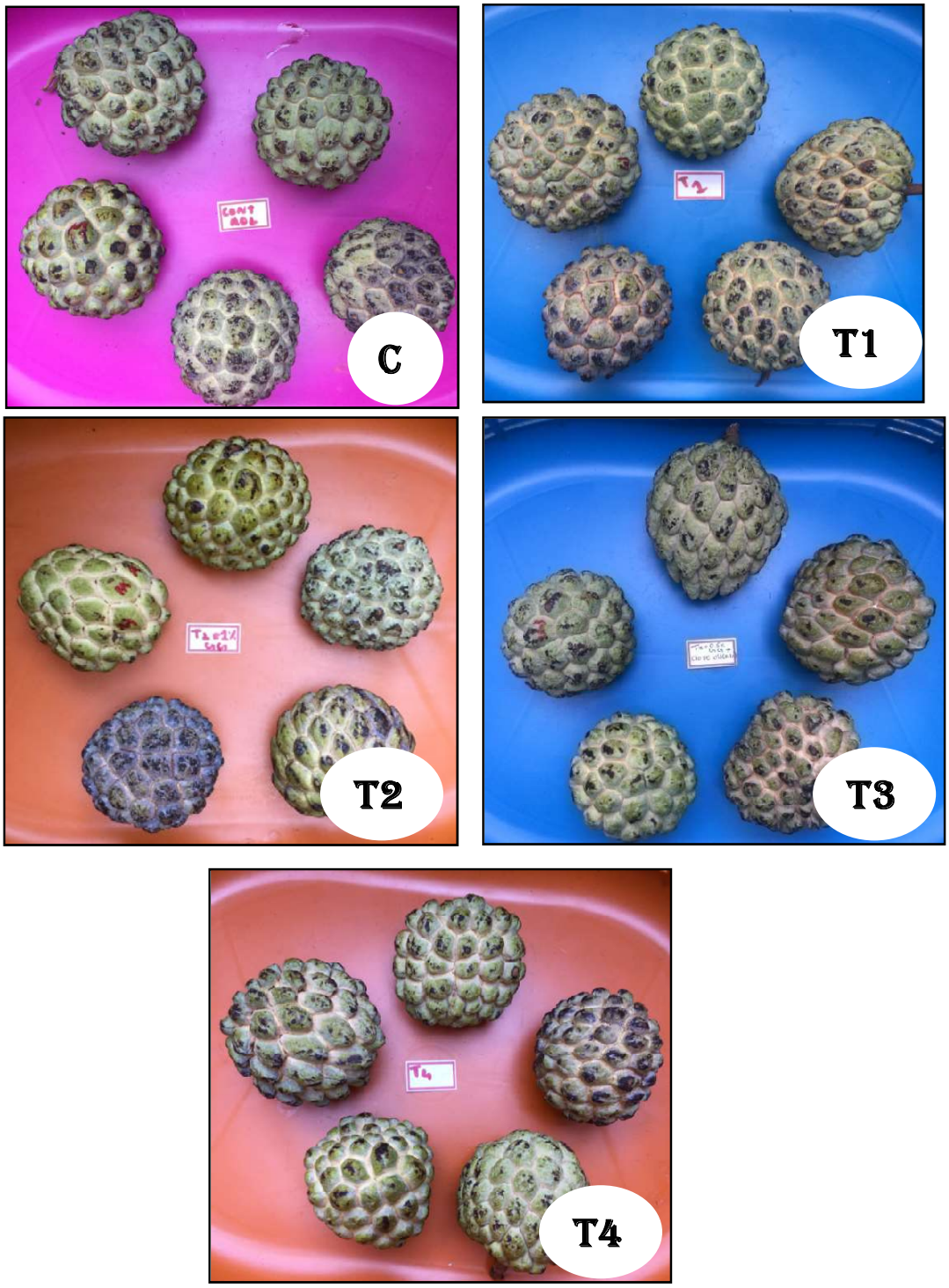


PLATE 1.3

PLATE 1.4

Effect of guar gum based edible coating on visual quality of custard apple on 6th day of storage

T1 – 0.5% Guar gum

T2 – 1% Guar gum

T3 – 0.5% Guar gum + 0.1% clove oil

T4 – 1% Guar gum + 0.1% clove oil

C - Control

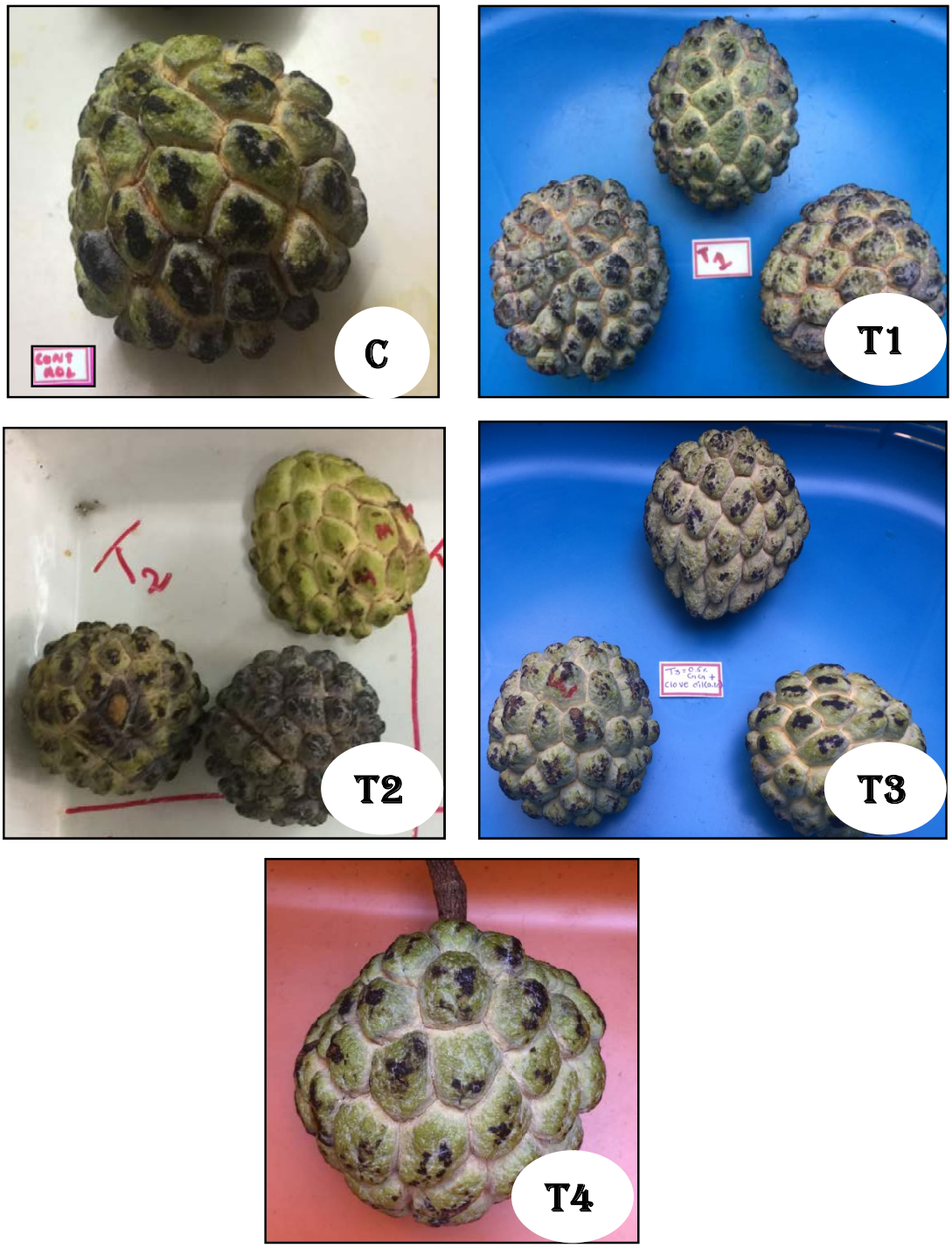


PLATE 1.4

PLATE 1.5

Effect of guar gum based edible coating on visual quality of custard apple on 8th day of storage

T1 – 0.5% Guar gum

T2 –1% Guar gum

T3 – 0.5% Guar gum + 0.1% clove oil

T4 – 1% Guar gum + 0.1% clove oil

C - Control

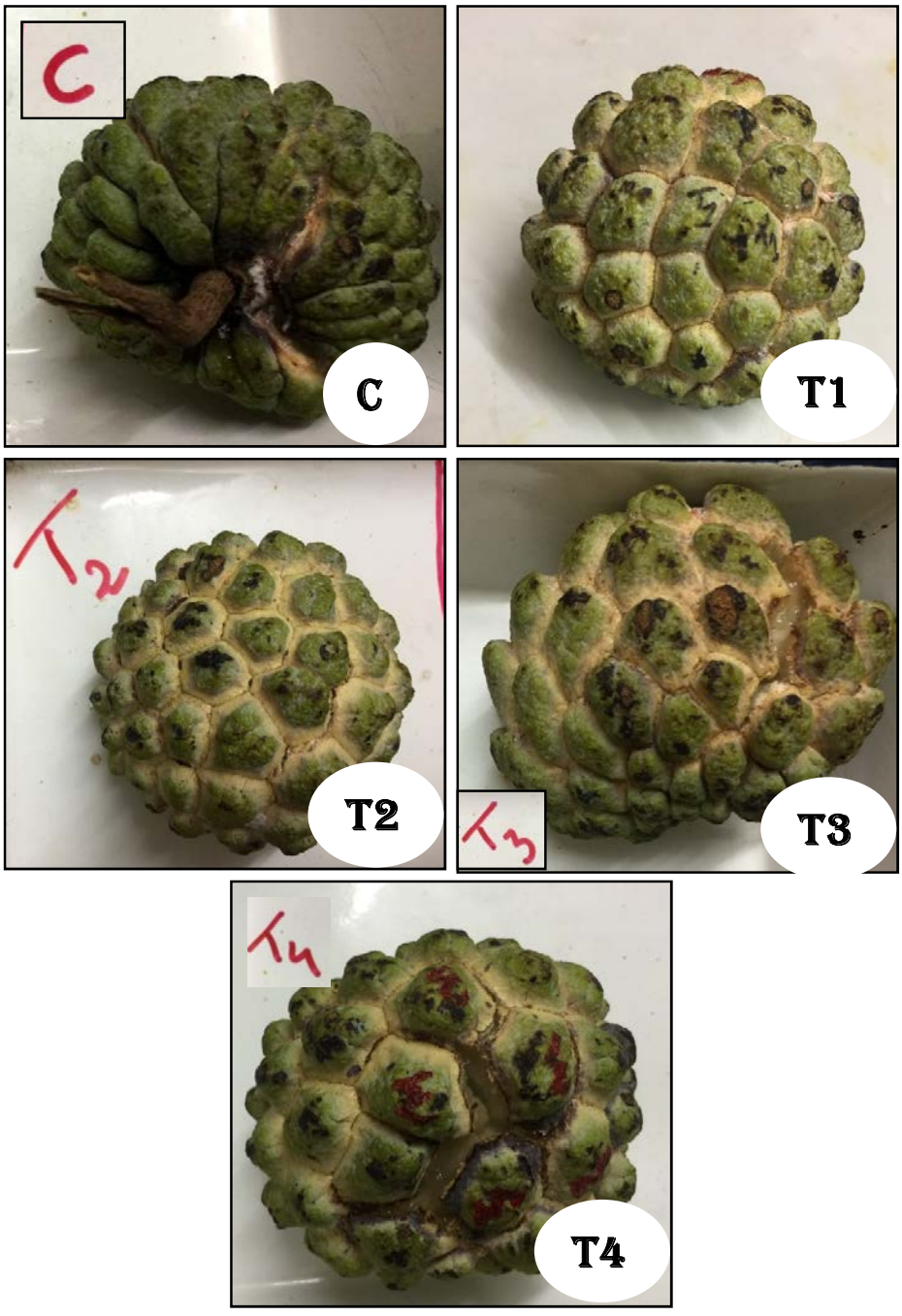


PLATE 1.5

2. Guava (*Psidium guajava* L.)

Introduction:

Guava (*Psidium guajava*) is one of the important commercial fruits in India. It is the fourth most important fruit after mango, banana and citrus. It is normally consumed fresh as a dessert fruit, or processed into puree, juice, concentrate, jam, jelly, nectar or syrup (Jagtiani et al., 1988).

Guava is said to be originated in American tropics (actual place unknown) and belonging to the Family Myrtaceace comprising 80 genera with the major important genera of Guava (*Psidium*), jamun etc. and 3000 species. Guava grows well in tropical conditions, but tolerates -2°C, best at 23-28°C. It also grows at lower temperatures but fruit maturity time is longer. In India, it is 6th most widely grown fruit, occupying an area of 1.8 lakh ha, with an annual production of 19.8 lakh MT (Anon, 2009). It also has problem of diseases and pests; (i) Diseases – Anthracnose on fruit; Blossom end rot, mucor fruit rot; Many other fungi, minor impotance and (ii) Pests – many insects and mites, Fruit flies – Oriental, mediterraanean, Natal; Thrips – leaves and fruit; Scales; Guava fruit fly, Guava moth. Due to perishable nature, under ambient conditions fruits become overripe and mealy within a week, whereas, in cold storage guava cv. 'Allahabad Safeda' fruit are reported to be maintained quality up to 15 days at 8-10°C and 85-90% RH (Tondon et al., 1989). Therefore, it needs immediate marketing and utilization after harvesting. During storage, physic-chemical and biochemical changes affect the final texture and quality of fruits. The share of the guava fruits, export from India is not enough (0.65%), which can boosted up with the increasing storability of fruits. In view of forgoing account the guava fruit is selected as one of the fruits for the present investigation.

Collection of guava fruit:

The guava fruits of 'Apple' variety (78 Kg) were procured at their commercial mature stage from village Savli near Vadodara. These fruits were then disinfected with 0.2% sodium hypochlorite solution for 5 minutes. The guava fruits were put into eight groups and each group consisted of 10 fruits. The following eight treatments were selected for the guava fruit:

(1) **T1** – 1 % Gum Acacia; (2) **T2** – 2% Gum Acacia; (3) **T3** – Ozone water (10 min); (4) **T4 -** 1 % Gum Acacia + 0.1% clove oil + Ozone water (10 min); (5) **T5** – 2 % Gum Acacia + 0.1% clove oil + Ozone water (10 min); (6) **T6 -** 1 % Gum Acacia + 0.1% Cinnamon oil + Ozone water (10 min); (7) **T7 -** 2 % Gum Acacia + 0.1% Cinnamon oil + Ozone water (10 min) and (8) **T8** – Control. The dipping method was used for 5 minutes followed by air drying and stored at 24°C±2°C.

The fruits samples were then subjected to physic-chemical analysis and biochemical analyses at a regular interval of 3 days.

Results:

Effect on Weight loss percentage (WLP)

As represented in Table 2.1 and Figure 2.1, the coated guava fruit showed lesser WLP as compared to uncoated guava on 8th day of storage. The application of 2% gum acacia alone and in combination with 0.1% cinnamon oil and ozone water treatment help reduced WLP (~21%) to the higher level as compared to the other treatments during 8 days of storage period. The highest WLP was observed in uncoated guava fruit ~40% at the end of storage period. However the application gum acacia based edible coatings help reducing the weight loss of guava during 8 days of storage time. Reduction in weight loss is probably due to effect of the coating as semi permeable barrier against O_2, CO_2, moisture and solute movement thereby reducing respiration, water loss and oxidation reduction rates.

Table 2.1: Effect of gum acacia based edible coatings on weight loss percentage of guava fruit during their storage at 24°C.

	Storage period (Days)		
	Weight loss percentage		
Treatments	0	4	8
T1	0	8.50±1.55	32.06±4.78
T2	0	8.47±0.95	21.76±5.37
T3	0	8.50±1.55	32.06±4.78
T4	0	7.77±2.17	24.60±6.54
T5	0	10.20±1.26	30.52±3.78
T6	0	7.39±0.64	28.95±5.16
T7	0	8.53±1.63	20.86±5.39
C	0	8.83±1.58	40.35±3.70

Effect on TSS and pH

At 0 day of storage, TSS measured in fresh guava was 9.67±0.58 °Brix. The result regarding the trend of TSS in coated and uncoated guava during storage period of 8 days is presented in Table 2.2 and Figure 2.1, revealed that T3 samples maintained TSS during 8 days of storage, while T2 and T6 exhibited slight decline at the end of storage time. The highest TSS (13.0±1.0°Brix) was measured in T7 and the lowest value (8.33±0.58°Brix) was found in T2 and T6 coated guava, whereas the TSS of T1, T3 and T4 had increased to 11.0±0.0°Brix which is close to the value of TSS noted in uncoated guava fruit (11.33±0.58 °Brix) at the end of storage. These results showed that the gum acacia alone and in combination with cinnamon oil posses the role in delaying the ripening process of guava fruit. The data presented in Table 2.2 and Figure 2.1, indicated that both coated and uncoated guava fruit exhibited slight increase in the pH value during 8 days of storage time with insignificant difference among coated as well as with uncoated samples.

Effect on Total sugars

The concentration of total sugars present in fresh guava fruit was 3.28±0.43 mg/g FW. The application of 2% gum acacia on guava fruit helped delayed the rise in total sugars content as compared to 1% gum acacia coated fruit during 8 days of storage time (Table 2.2 and Figure 2.2). During 8 days of storage period ozone water treated guava (T3) and gum acacia in combination with 0.1% clove oil treated samples maintained the initial amount of total sugars, though exhibited significant increment on 4^{th} day of storage. On the contrary, the application of 1% gum acacia in combination with 0.1% cinnamon oil on guava fruit did not help in reducing the declining pattern of total sugars and reached to the lowest value (1.53±0.39 mg/g), near to the amount of total sugars present in uncoated guava fruit (1.66±0.27 mg/g) at the end of storage time. However, the application of 2% gum acacia+0.1% cinnamon oil better retained the amount of total sugars over the entire storage time.

Table 2.2: Effect of gum acacia based edible coatings on total soluble solids, pH and total sugars of guava fruit during their storage at 24°C.

Treatments	Storage period (Days)		
	Total soluble solids		
	0	4	8
T1	9.67±0.58	9.33±0.58	11.0±0.0
T2	9.67±0.58	10.0±0.0	8.33±0.58
T3	9.67±0.58	11.0±0.0	9.33±0.58
T4	9.67±0.58	10.33±0.58	11.0±0.0
T5	9.67±0.58	10.0±0.0	11.0±0.0
T6	9.67±0.58	8.33±0.58	8.33±0.58
T7	9.67±0.58	8.67±0.58	13.0±1.00
C	9.67±0.58	10.0±0.0	11.33±0.58
	pH		
	0	4	8
T1	4.3±0.0	5.09±0.01	5.01±0.04
T2	4.3±0.0	4.78±0.01	4.74±0.01
T3	4.3±0.0	4.71±0.01	4.7±0.00
T4	4.3±0.0	4.72±0.01	4.82±0.01
T5	4.3±0.0	4.70±0.01	4.78±0.01
T6	4.3±0.0	4.82±0.01	4.85±0.02
T7	4.3±0.0	4.77±0.01	4.66±0.01
C	4.3±0.0	4.87±0.00	4.64±0.01
	Total sugars		
	0	4	8
T1	3.28±0.43	4.63±0.24	5.34±0.24
T2	3.28±0.43	4.13±0.68	4.25±0.55
T3	3.28±0.43	4.01±0.53	3.63±0.38
T4	3.28±0.43	4.09±0.29	3.20±0.56
T5	3.28±0.43	4.72±0.45	3.48±0.51
T6	3.28±0.43	2.52±0.47	1.53±0.39
T7	3.28±0.43	2.51±0.42	2.67±0.49
C	3.28±0.43	2.10±0.42	1.66±0.27

Effect on Ascorbic acid

It was observed that the concentration of ascorbic acid in both the coated and uncoated guava measured on 4 day of storage was approx. 2.6 fold greater than that recorded in fresh guava fruit except T3 and T6 samples, as represented in Table 2.3 and Figure 2.2.

Table 2.3: Effect of gum acacia based edible coatings on ascorbic acid, total phenol and antioxidant activity of guava fruit during their storage at 24°C.

Treatments	Storage period (Days)		
	Ascorbic acid		
	0	4	8
T1	0.73±0.07	1.65±0.07	1.33±0.01
T2	0.73±0.07	1.95±0.05	1.34±0.04
T3	0.73±0.07	1.58±0.11	1.58±0.14
T4	0.73±0.07	2.04±0.15	1.51±0.17
T5	0.73±0.07	1.8±0.17	2.03±0.13
T6	0.73±0.07	1.41±0.10	1.32±0.09
T7	0.73±0.07	1.99±0.18	1.76±0.11
C	0.73±0.07	1.92±0.10	1.65±0.11
	Total phenol content		
	0	4	8
T1	6.73±0.14	8.42±0.65	6.63±0.31
T2	6.73±0.14	6.61±0.16	4.52±0.03
T3	6.73±0.14	5.43±0.29	5.10±0.12
T4	6.73±0.14	5.54±0.24	5.52±0.07
T5	6.73±0.14	5.26±0.03	8.82±0.71
T6	6.73±0.14	6.57±0.27	6.75±0.01
T7	6.73±0.14	7.61±0.29	5.86±0.39
C	6.73±0.14	6.48±0.30	6.42±0.55
	Antioxidant activity (%)		
	0	4	8
T1	58.21±0.34	54.49±1.07	95.74±0.29
T2	58.21±0.34	44.56±0.99	89.81±0.17
T3	58.21±0.34	40.06±0.69	94.96±0.07
T4	58.21±0.34	38.91±0.49	95.43±0.09
T5	58.21±0.34	39.28±1.91	96.30±0.13
T6	58.21±0.34	48.02±3.77	95.37±0.21
T7	58.21±0.34	50.94±0.65	95.69±0.04
C	58.21±0.34	45.79±2.53	95.74±0.39

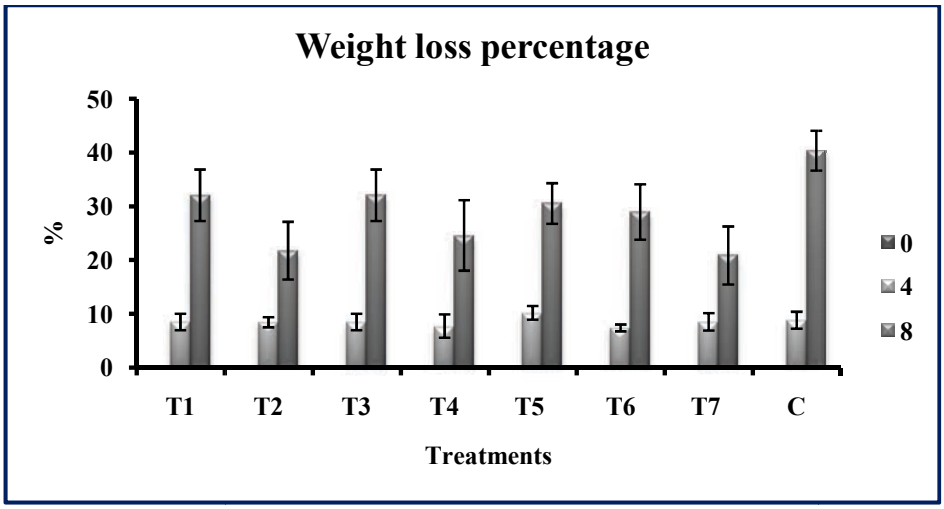
These higher values probably due to greater water loss in these guava samples as compared to T3 and T6 coated guava fruit and not because of its biosynthesis.

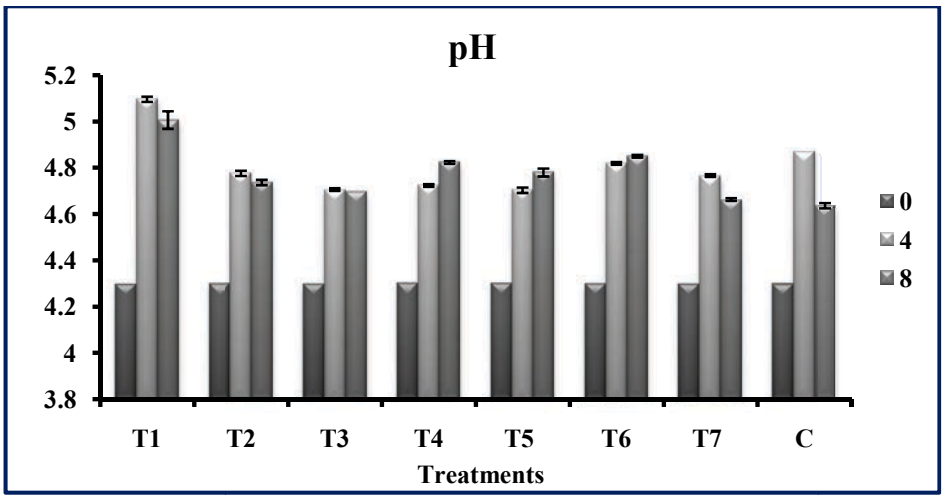
Effect on Total phenol content and Antioxidant activity

The result regarding the changing behavior of total phenols due to application of gum acacia alone and in combination with clove oil, cinnamon oil and ozone water is presented in Table 2.3 and Figure 2.3. At 0 day of storage time, the amount of total phenol was 6.73±0.14 mg/g FW. Among the coated samples, the highest concentration of total phenol (8.82±0.71 mg/g FW) was recorded in T5, while the lowest of it (4.52±0.03 mg/g FW) was measured in T2 at the end of evaluation time. T6 and control guava fruit exhibited least change during 8 days of storage time. This indicated that in general the total phenol content of guava fruit did not exhibited significant change during 8 days of storage.

The antioxidant activity observed in guava fruit at 0 day of storage was 58.21±0.34%, as represented in Table 2.3 and Figure 2.3. On 4^{th} day of storage, the decrement was recorded depending on the applied treatments. The least decline was found in T1 guava samples (~6%), while highest was obtained in T4 and T5 samples (~33%). Thereafter on 8^{th} of storage, it increased from ~58% to 95% of antioxidant activity in all coated and uncoated samples.

Figure 2.1: Effect of gum acacia based edible coating on weight loss percentage (WLP), TSS and pH of guava.





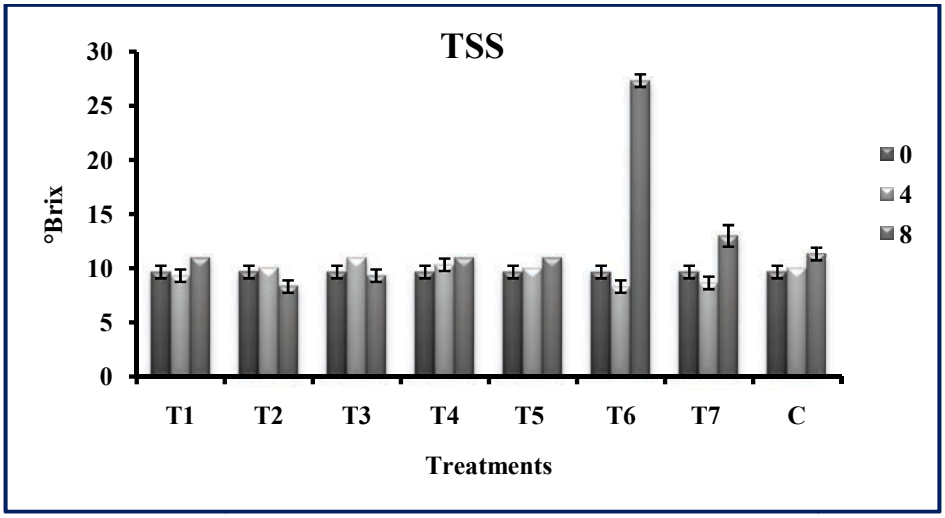
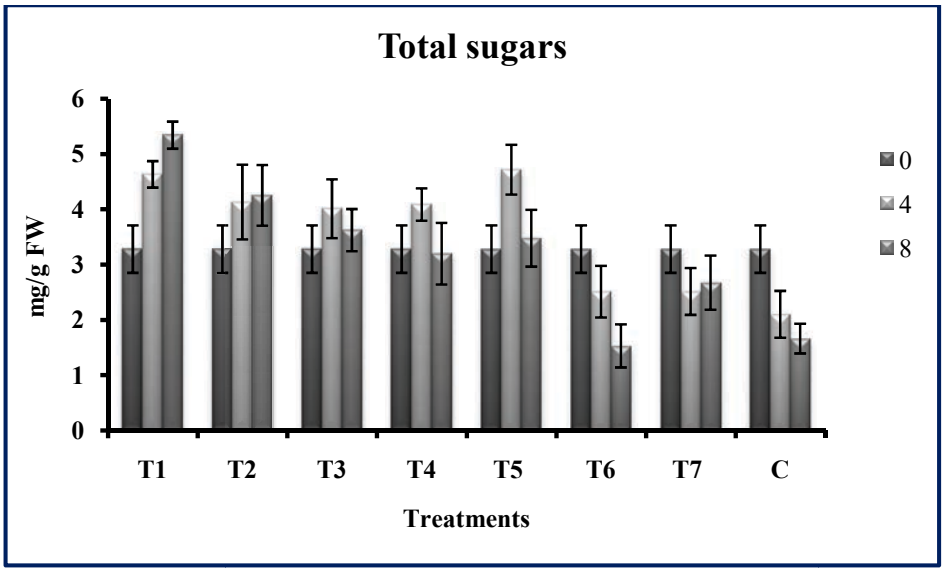


Figure 2.2: Effect of gum acacia based edible coating on total sugars and ascorbic acid of guava.



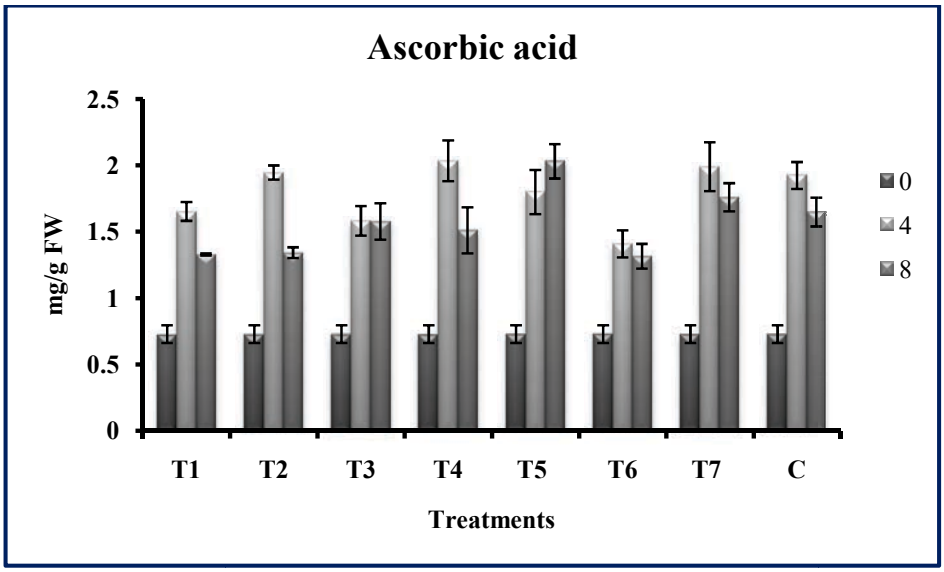
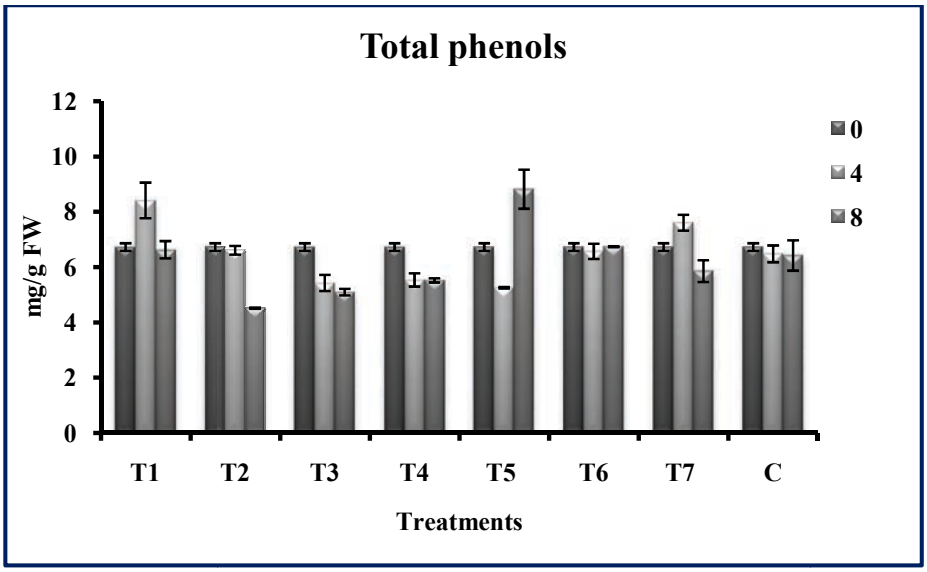


Figure 2.3: Effect of gum acacia based edible coating on total phenols and antioxidant activity of guava.



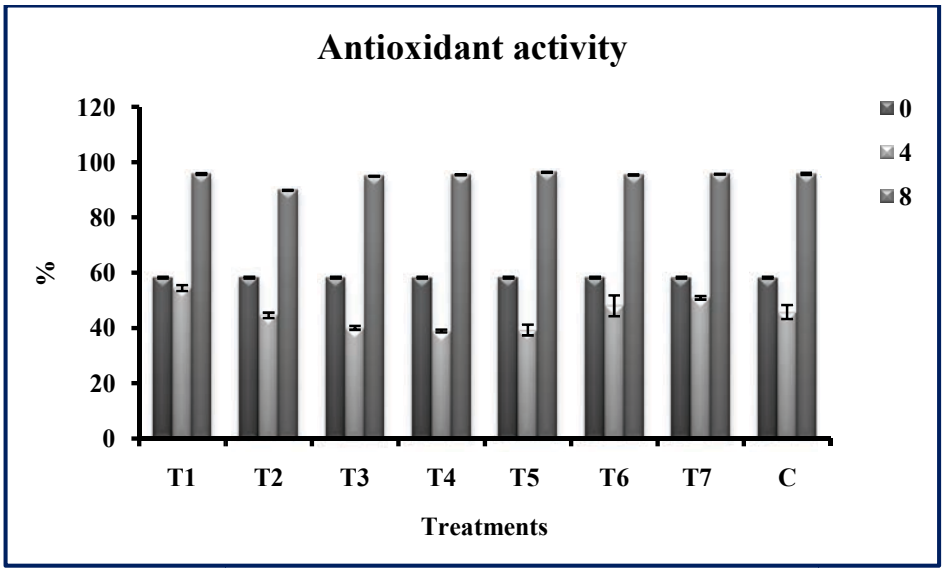


PLATE 2.1

A – Guava fruit farm, village Savli near Vadodara.

B – Guava fruit Custard apple kept for air drying after surface disinfection with 0.2% sodium hypochlorite solution.

C – 1% Gum acacia solution

D – 2% Gum acacia solution

E – 1% Gum acacia solution + 0.1% Cinnamon oil

F – Ozone water collected in bottle

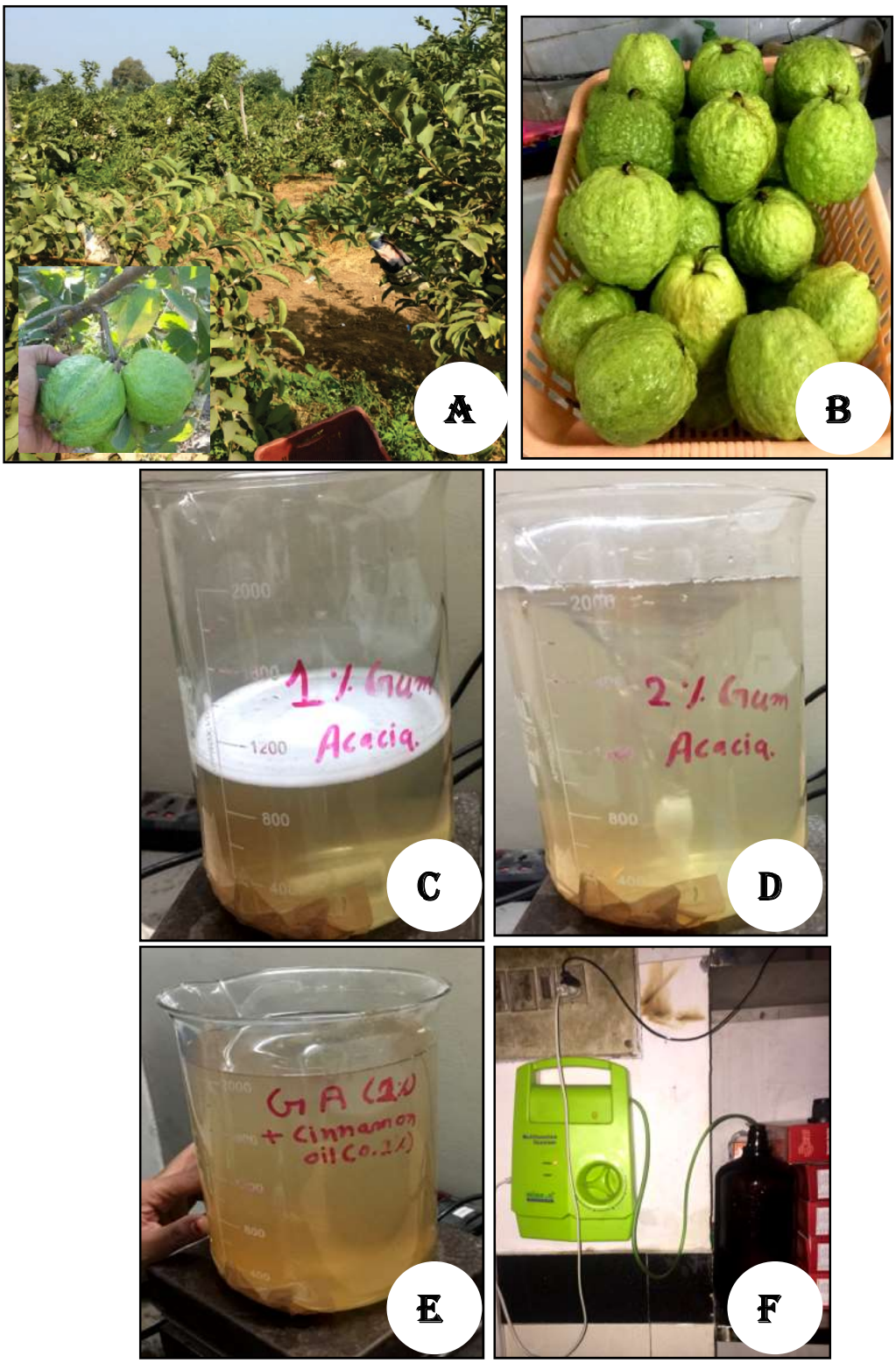


PLATE 2.1

PLATE 2.2

Effect of gum acacia based edible coatings on visual quality of guava fruit on 4th day of storage

T1 – 1% Gum Acacia

T2 – 2% Gum Acacia

T3 – Ozone water (10 min)

T4 – 1% Gum Acacia + 0.1% clove oil + Ozone water (10 min)

T5 - 2% Gum Acacia + 0.1% clove oil + Ozone water (10 min)

T6 - 1% Gum Acacia + 0.1% Cinnamon oil + Ozone water (10 min)

T7 - 2% Gum Acacia + 0.1% Cinnamon oil + Ozone water (10 min)

C - Control

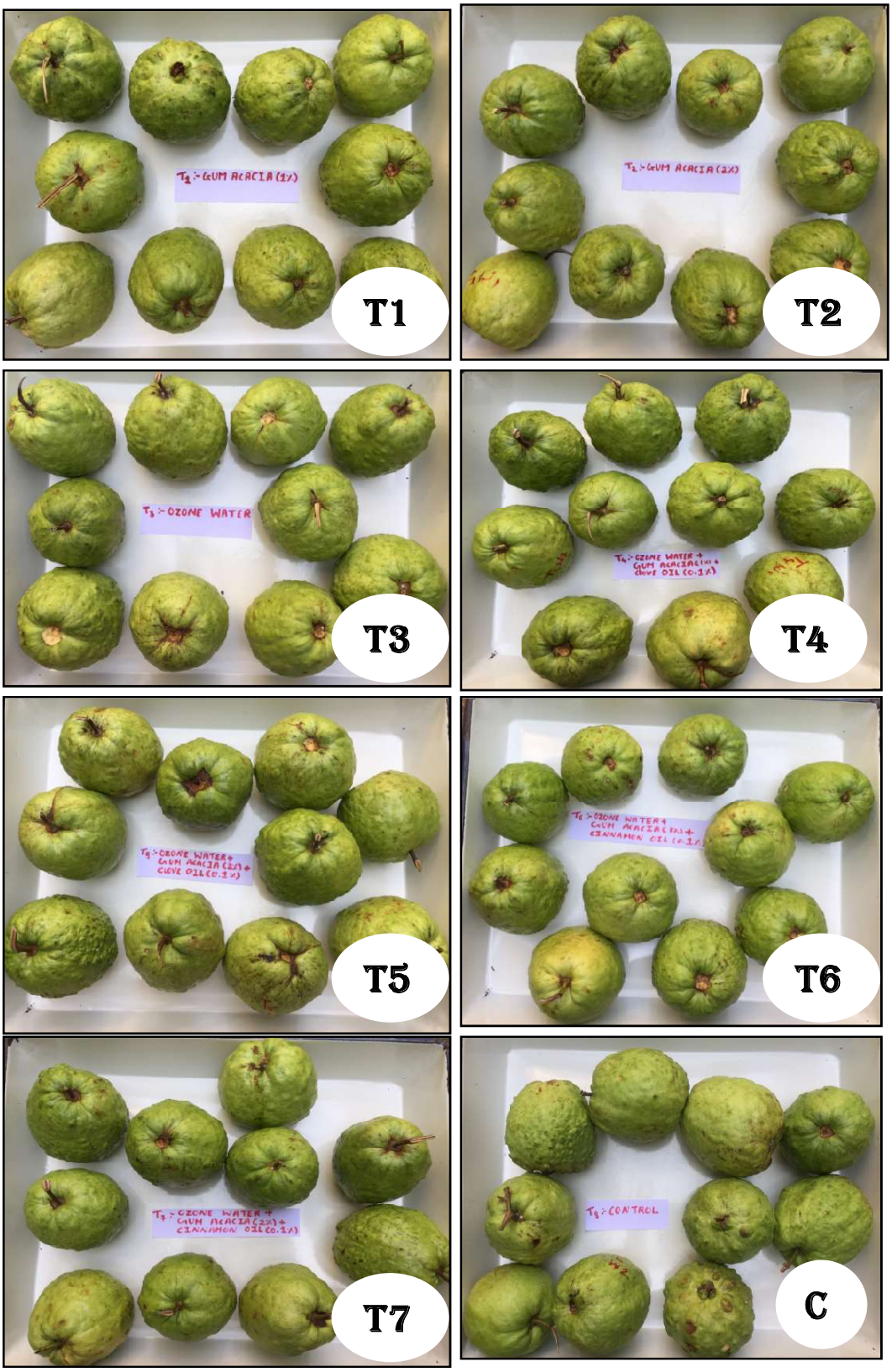


PLATE 2.2

PLATE 2.3

Effect of gum acacia based edible coatings on visual quality of guava fruit on 8th day of storage

T1 – 1% Gum Acacia

T2 – 2% Gum Acacia

T3 – Ozone water (10 min)

T4 – 1% Gum Acacia + 0.1% clove oil + Ozone water (10 min)

T5 - 2% Gum Acacia + 0.1% clove oil + Ozone water (10 min)

T6 - 1% Gum Acacia + 0.1% Cinnamon oil + Ozone water (10 min)

T7 - 2% Gum Acacia + 0.1% Cinnamon oil + Ozone water (10 min)

C - Control

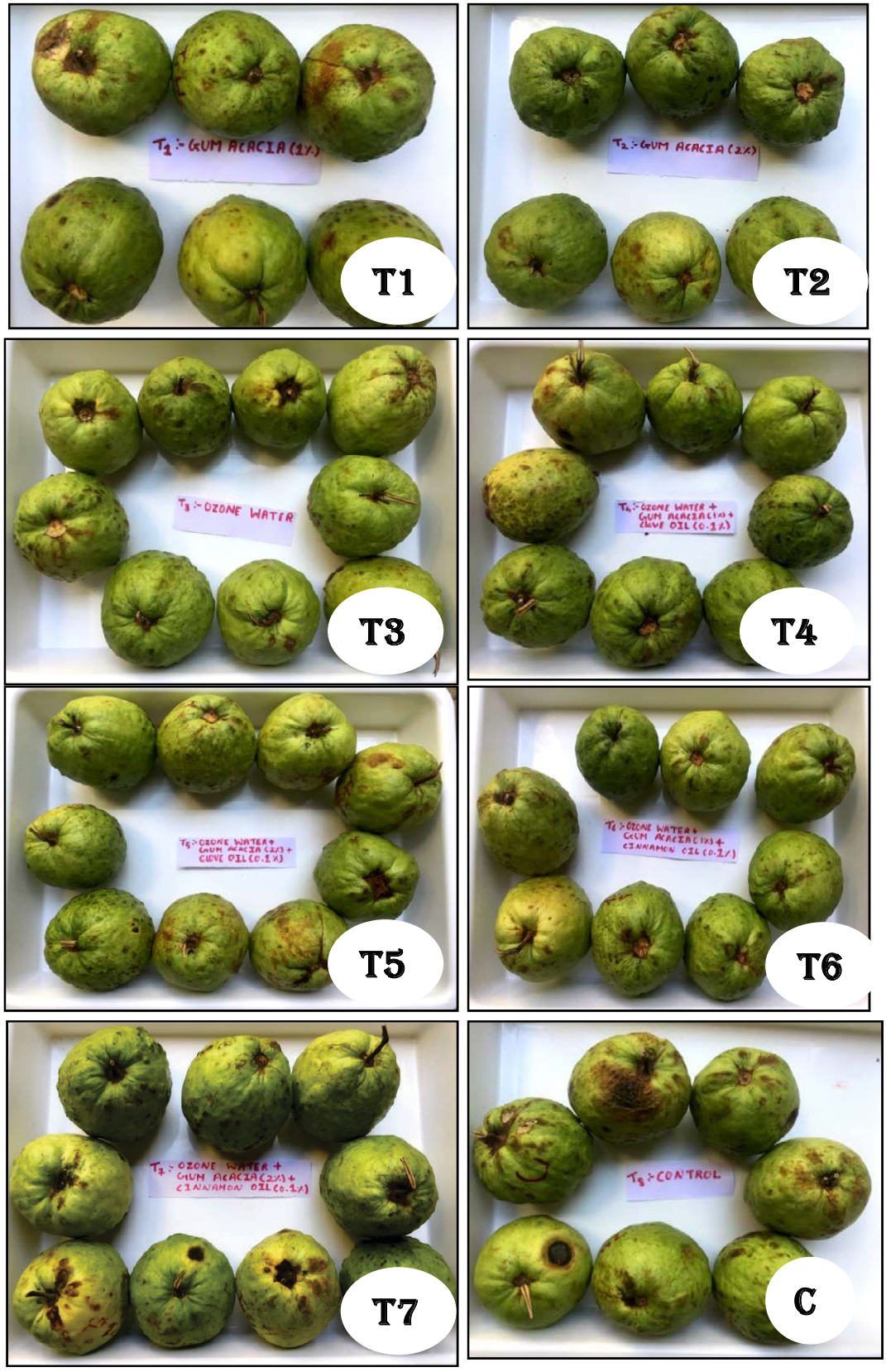


PLATE 2.3

3. Grape fruit *(Vitis vinifera*)

Introduction:

Grape, belong to the family Vitaceae, one of the world's most widely grown fruit crops in relatively warm temperate-zone climates. Grape fruits develop as clusters with each berry attached to the bunch stem (rachis and branches) via a pedicel which contains vascular bundles. The mature grape berry is a non-climacteric fruit with a low rate of post-harvest physiological activity. Grapes must therefore be harvested after they have reached optimum levels of color development and of important solutes such as sugars and acids. It is available both as fresh fruit and processed in wine, grape juice, molassa, and raisins. The reason to have these different processed products depends on the extreme perishability of the fruit. As fresh fruit, grapes are very delicate and the loss at harvest and during the distribution is very high. The development of the post-harvest technology for grapes has concentrated on the fresh fruit. This is because all the eating-quality parameters (appearance, texture and taste) must be high in the commercial product.

The vine and developing fruits are susceptible to a number of pests and diseases (Pearson & Goheen, 1988). Fungal diseases can dramatically affect production. During wet weather, grey mould (*Botrytis cinerea*), downy mildew (*Plasmopora viticola*), anthracnose (*Elsinoë ampelina*) and phomopsis (*Phomopsis viticola*) are serious problems. Powdery mildew (*Uncinula necator* syn. *Erysiphe necator*) can occur in both wet and dry regions. Crown gall (*Agrobacterium* spp.) is the most serious bacterial disease, and there are a number of viruses that damage the vine (Jackson & Looney, 1999; Patil et al., 1995). Traditionally, sulphur dioxide (SO_2) is used to control grey mould. Standard practice is to fumigate with SO_2 immediately after harvesting and/or packing followed by lower dose SO2 treatments weekly during storage. Usually this initial fumigation uses a high level of SO_2 (up to 5000 ppm) and may be carried out in specially constructed rooms and the excess SO_2 is removed from the treatment chamber by venting or scrubbing through water or sodium hydroxide aqueous solution after a treatment period of about 20 min. One of the problems associated with SO_2 fumigation of grapes is the constant severe damage to the berries and rachis. Injured tissue first shows bleaching of color, followed by sunken areas where accelerated water loss has occurred.

Another problem with SO2 fumigation of grapes is the level of sulphite residue remaining at time of final sale, which could be harmful to the sulphite allergic people. These are the reason related to human health and environmental pollution stimulated the search for new strategies as alternative tools for controlling postharvest decay. Therefore, the present study was undertaken to explore the *Aloe vera* gel as naturally derived edible coating alone or in combination with clove oil for postharvest quality maintenance of table grapes.

Collection of fruit and application of treatments

The fresh grape fruit were collected from wholesale fruit market of Anand (Gujarat) and with uniform maturity and with no signs of mechanical damage or microbial decay. After sanitization in 2% solution of sodium hypochlorite (NaOCl) for 10 minutes and air dried at room temperature. These fruits were grouped into eight sets having three units in each set. Of these, seven sets were kept as experimental sets, while the eighth was treated as control set. And subsequently they were subjected to the following *Aloe vera* based edible coating treatments by dipping for 2-3 min: (1) T1 - 5% *Aloe* gel, (2) T2 – 10% *Aloe* gel, (3) T3 – 25% *Aloe* gel, (4) T4 – 50% *Aloe* gel, (5) T5 - 100% *Aloe* gel, (6) T6 – 10% *Aloe* gel + 0.5% clove oil, (7) T7 – 10% *Aloe* gel + 1% clove oil and (8) Control. The treated sample were kept to air dry at room temperature and stored at 25±2°C. These stored fruits were subjected to their physicochemical and biochemical analyses at 0 day and after regular interval of 4 days of storage.

Results:

Effect on Weight loss percentage (WLP)

The weight loss is mainly related to respiration rate and moisture evaporation from fruits. Weight loss percentage (WLP) of grapes was significantly lesser in samples coated with 10%, 25%, 50% and 100% *Aloe* gel as compared to samples coated with 10% *Aloe* gel in combination with clove oil (0.5% and 1%) and uncoated samples during 24 days of storage at 25°C (Table 3.1 and Figure 3.1). Among *Aloe* gel coated samples, concentration of *Aloe* gel at 25%, 10% and 5% were observed with 4.95, 8.82 and 11.76 units of WLP respectively at 12 days of storage time which indicating that increasing the

Aloe gel concentration helped delayed in reducing WLP of grapes. Contrarily, 50% and 100% *Aloe* gel use did not affect in maintaining the lesser WLP of grapes as compared to uncoated samples. Moreover the incorporation of clove oil at 0.5% and 10% into *Aloe* gel (10%) and its use as edible coating on grapes showed negative effect of WLP as it was comparatively higher in these samples than uncoated samples. After 16th day of storage, the acceleration of weight loss was noted to be higher in uncoated, 50% and 100% *Aloe* coated samples than that observed in 10% and 25% *Aloe* coated samples. The accelerated weight loss can be attributed to an increase in the metabolic activity of fruit, associated with tissue senescence over long storage times, which are slowed down after coating application (Sánchez-González et al., 2011).

Table 3.1: Effect of *Aloe vera* gel based edible coating on weight loss percentage (WLP), TSS and pH of grapes.

Treatment	Storage period (Days)						
	Weight loss percentage						
	0	4	8	12	16	20	24
Control	0	5.940594	12.87129	15.84158	17.82178	22.77228	25.74257
T1	0	5.882353	8.823529	11.76471	19.60784	23.52941	39.21569
T2	0	0.980392	3.921569	8.823529	14.70588	16.66667	20.58824
T3	0	0.990099	3.960396	4.950495	14.85149	17.82178	23.76238
T4	0	6.796117	9.708738	11.65049	12.62136	17.47573	22.3301
T5	0	5	9	12	15	20	31
T6	0	11.88119	19.80198	19.80198	30.69307	33.66337	38.61386
T7	0	9.803922	15.68627	24.5098	45.09804	49.01961	57.84314

Effect on total soluble solids (TSS) and pH

At 0 day of storage, TSS of grapes was 13.33±0.58 which ultimately increased to 16.33±0.58 in control samples after 20 days at 25°C (Table 3.2 and Figure 3.1). This increment was significantly delayed in *Aloe*-treated grapes. However, grapes treated with *Aloe* gel in combination with clove oil were found with greater rise in TSS as compared to uncoated samples and only *Aloe*-treated grapes throughout the storage. According to Tanada-Palmu and Grosso (2005), the increasing TSS during storage time may be the

consequences of higher water loss. The results of present study are in agreement with the previous study conducted by Valverde et al. (2005) on table grapes.

The pH value of grape at 0 day of storage was 3.50±0.15 which showed remarkable increment mainly during first 4-8 days of storage in all the grapes samples and thereafter declined slightly by 16 days of storage and again increased at the end of storage period (Table 3.2 and Figure 3.1).

Table 3.2: Effect of *Aloe vera* gel based edible coating on total soluble solids, pH and total sugars of grapes.

Treatments	Storage period (Days)						
	Total soluble solids						
	0	**4**	**8**	**12**	**16**	**20**	**24**
Control	13.33±0.58	11.67±0.58	13±0.0	12.67±0.58	15.33±0.58	16.33±0.58	0
T1	13.33±0.58	16.67±0.58	15.67±0.58	16.33±0.58	14.0±1.0	15.33±0.58	15.67±0.58
T2	13.33±0.58	13.0±1.0	16.67±0.58	15.0±1.0	18.0±0.0	14.33±0.58	16.0±0.0
T3	13.33±0.58	12±1.0	17.33±0.58	18.0±1.0	13.0±0.0	14.67	16.67±0.58
T4	13.33±0.58	11.33±0.58	11.67±0.58	14.0±0.0	12.67±0.58	13.0±0.0	15.0±0.0
T5	13.33±0.58	15.33±0.58	18.0±0.00	14.33±0.58	13.33±0.58	16.67±0.58	0
T6	13.33±0.58	13.67±0.58	15.67±0.58	13.33±0.58	17.33±0.58	19.0±0.0	14.33±0.58
T7	13.33±0.58	14.0±0	18.0±0.0	18.0±1.0	14.67±0.58	18.33±0.58	17.33±0.58
	pH						
	0	**4**	**8**	**12**	**16**	**20**	**24**
Control	3.50±0.15	3.93±0.006	4.02±0.10	3.66±0.01	3.96±0.03	3.85±0.006	0
T1	3.50±0.15	4.16±0.015	3.77±0.015	3.97±0.017	3.95±0.02	3.13±0.01	4.08±0.053
T2	3.50±0.15	3.89±0.006	4.32±0.021	4.15±0.025	4.10±0.01	3.63±0.047	4.04±0.017
T3	3.50±0.15	3.88±0.01	4.38±0.01	4.26±0.021	3.70±0.01	3.58±0.01	4.00±0.006
T4	3.50±0.15	3.66±0.01	3.58±0.03	3.97±0.006	3.74±0.01	3.50±0.006	3.79±0.01
T5	3.50±0.15	4.03±0.57	4.27±0.021	3.97±0.006	3.86±0.02	3.56±0.01	0
T6	3.50±0.15	4.24±0.006	4.11±0.023	3.99±0.015	4.11±0.01	3.73±0.00	3.77±0.042
T7	3.50±0.15	4.13±0.006	3.89±0.025	4.31±0.012	4.13±0.01	3.81±0.012	3.84±0.0
	Total sugars						
	0	**4**	**8**	**12**	**16**	**20**	**24**
Control	45.41±3.99	18.66±2.68	171.13±2.62	83.79±3.03	170.48±1.70	169.13±2.87	0
T1	45.41±3.99	19.60±2.65	97.35±1.85	47.02±2.35	154.24±1.39	120.74±1.92	79.83±1.78
T2	45.41±3.99	38.99±2.85	32.51±3.58	54.12±2.17	98.28±2.31	113.01±3.33	74.86±1.67
T3	45.41±3.99	42.47±3.89	27.47±4.19	38.28±1.50	56.53±2.72	162.14±3.59	68.32±2.57
T4	45.41±3.99	17.27±3.88	138.33±3.56	89.45±2.10	17.70±2.18	157.24±1.16	60.26±2.96
T5	45.41±3.99	13.85±1.57	129.54±1.87	27.20±0.82	87.35±2.27	143.38±2.06	0
T6	45.41±3.99	25.90±1.85	37.15±3.84	36.70±1.39	38.54±1.79	136.42±2.47	64.58±1.70
T7	45.41±3.99	10.44±1.76	9.26±1.82	98.76±1.16	140.04±2.06	163.01±2.14	75.44±2.11

Effect on Total sugars

The data presented in Table 3.2 and Figure 3.2 revealed that the uncoated grapes were found with increasing value of total sugars during storage time of 24 days. In general, the total sugars were declined during initial 4 days of storage in all coated and uncoated grapes. However, thereafter the changing behavior was varying among treated samples and control samples. While considering the total sugars of coated samples, the least change was observed in T6 followed by T3 and T2 samples of grapes up to 16 days of storage but thereafter the amount of total sugars increased on 20^{th} day of storage and again decreased at the end of storage. The initial reduction in the total sugars may be the result of its consumption as source of energy due to ripening process and afterward increment of total sugars might be due to the conversion of stored starch into sucrose, fructose and glucose, catalyze by the activity of amylase. This can be inferred that the application of 10% *Aloe* gel in combination with 0.5% clove oil help delayed the mechanisms involved in fruit ripening and decaying as result of creating semipermeable barrier against water loss and gas exchange.

Effect on Ascorbic acid

Ascorbic acid also known as Vitamin C, when pure is white crystalline water - soluble vitamin found especially in citrus fruits and vegetables. Ascorbic acid is the most abundant vitamin in orange, lemon and grape fruit. There is a considerable variation in the ascorbic acid content of juice of different fruit (Luisa et al., 2014). Vitamin C is the most important Vitamin for human nutrition that is supplied by fruits and vegetables. It is a valuable food component because of its antioxidant and therapeutic properties (Okiei et al., 2009). Vitamin C is an essential phytonutrients for the metabolism of living cells, that occurs in different concentrations in natural foods especially fruits and their products. It is considered as the major antioxidant in the diet (Mahdavi et al., 2010). It was observed that the vitamin C concentration in uncoated grapes was 0.64±0.19 mg/g at 0 day of storage, increased to 1.24±0.27 mg/g on 8^{th} day of storage and thereafter declined to 0.87±0.13 mg/g at the end of storage time (Table 3.3 and Figure 3.2). The treatment of grapes with *Aloe* gel showed significant increment in vitamin C content during 12 – 16 days of storage and afterward declining pattern was noted till the end of storage. Among

the coated grapes, the vitamin C content retained maximum in 25% *Aloe*-treated samples e.g. 1.25±0.16 mg/g at 24th day of storage. The rate of degradation of vitamin C depends on the temperature and residual oxygen level and its degradation occurs in two different conditions, aerobic and anaerobic. In aerobic conditions, ascorbic acid oxidizes to dehydroascorbic acid followed by hydrolysis and oxidation to form diketogulonic acid and oxalic acid. In anaerobic conditions there is a series of dehydrations and hydrolyses, finally giving furfural and carbon dioxide (Matei et al., 2009). Since the fruits were stored at 25°C and well ventilated food grade storage boxes, the grapes both coated and uncoated samples did not showed significant change in vitamin C value at 0 day and at end of storage time.

Table 3.3: Effect of *Aloe vera* gel based edible coating on ascorbic acid, total phenol and total flavonoids of grapes

	Storage period (Days)							
	Ascorbic acid							
	0	**4**	**8**	**12**	**16**	**20**	**24**	
Control	0.64±0.19	1.14±0.62	1.24±0.27	0.89±0.07	0.68±0.19	0.87±0.13		0
T1	0.64±0.19	1.68±0.13	0.66±0.12	1.37±0.21	2.4±0.76	0.74±0.07	0.58±0.10	
T2	0.64±0.19	1.32±0.36	0.95±0.21	1.28±0.62	1.56±0.51	1.05±0.09	0.86±0.15	
T3	0.64±0.19	1.26±0.24	0.93±0.13	1.64±0.24	2.10±0.65	1.01±0.05	1.25±0.16	
T4	0.64±0.19	1.87±0.13	0.75±0.27	1.00±0.33	1.53±0.50	1.11±0.13	0.91±0.13	
T5	0.64±0.19	1.05±0.13	1.16±0.03	1.31±0.47	2.58±0.63	2.26±0.13		0
T6	0.64±0.19	1.56±0.07	1.32±0.60	1.83±0.19	1.28±0.33	0.44±0.04	0.60±0.09	
T7	0.64±0.19	1.72±0.23	1.96±0.19	1.35±0.67	1.36±0.20	1.37±0.19	0.98±0.29	
	Total phenols							
	0	**4**	**8**	**12**	**16**	**20**	**24**	
Control	8.06±0.25	1.96±0.01	1.68±0.20	7.36±0.34	3.79±0.27	1.42±0.23		0
T1	8.06±0.25	2.73±0.05	1.74±0.04	2.46±0.11	2.46±0.04	2.53±0.73	1.94±0.11	
T2	8.06±0.25	1.87±0.11	2.84±0.36	2.20±0.22	5.06±0.08	2.03±0.25	1.65±0.13	
T3	8.06±0.25	1.65±0.08	2.78±0.19	3.04±0.24	3.97±0.17	2.06±0.19	1.49±0.11	
T4	8.06±0.25	3.11±0.11	2.91±0.16	2.56±0.10	4.05±0.09	6.94±1.27	1.52±0.27	
T5	8.06±0.25	4.67±0.26	3.82±1.78	4.31±0.17	3.65±0.16	1.88±0.14		0
T6	8.06±0.25	1.97±0.14	3.68±0.80	3.99±0.20	1.80±0.13	1.83±0.30	1.14±0.12	
T7	8.06±0.25	2.23±0.16	2.99±0.21	5.80±0.27	1.56±0.10	3.78±0.21	2.19±0.24	
	Total flavonoids							
	0	**4**	**8**	**12**	**16**	**20**	**24**	
Control	0.14±0.0006	0.13±0.0004	0.13±0.0005	0.10±0.0002	0.15±0.0005	0.09±0.0016		0
T1	0.14±0.006	0.11±0.0002	0.08±0.0015	0.22±0.0002	0.098±0.0011	0.08±0.0009	0.11±0.0005	
T2	0.14±0.006	0.16±0.0004	0.15±0.0012	0.13±0.0021	0.18±0.0006	0.09±0.0009	0.13±0.0006	
T3	0.14±0.006	0.17±0.0004	0.10±0.0001	0.17±0.0005	0.10±0.001	0.12±0.010	0.10±0.0019	

T4	0.14±0.006	0.22±0.0002	0.08±0.0015	0.12±0.0005	0.09±0.0	0.10±0.0036	0.14±0.0005
T5	0.14±0.006	0.24±0.0005	0.16±0.0002	0.10±0.0026	0.12±0.0	0.09±0.0002	0
T6	0.14±0.006	0.17±0.0002	0.19±0.0017	0.09±0.0001	0.13±0.0002	0.08±0.0002	0.11±0.0002
T7	0.14±0.006	0.17±0.0004	0.16±0.0006	0.16±0.0010	0.12±0.0007	0.09±0.0011	0.07±0.0004

Effect on total phenolic content and total flavonoids

The changes of total phenolics content of *Aloe*-treated and control grapes during storage are shown in Table 3.3 and Figure 3.3. At 0 day of storage, the phenolic content was 8.06±0.25 mg/g which sharply decreased to 1.68±0.19 up to 8 days in uncoated samples, while this reduction was delayed in treated samples. However, T1 and T5 coated samples showed consistently declining pattern of phenolic content throughout the storage period. The phenolic content decreased during storage that can be related to the postharvest fruit metabolic processes, such as respiration, ethylene production and enzyme activity. Furthermore, the decrease of total phenol content is probably due to the oxidation by polyphenol oxidase (PPO) (Altunkaya and Gökmen, 2008). At 12^{th} day of storage, uncoated samples exhibited sudden increment and thereafter abruptly declined at the end of storage. On the other hand, 10%, 25% and 50% *Aloe*-treated grapes showed slight enhanced values of phenolic content. Phenolic compounds are generally synthesized by the shikimate pathway in which phenylalanine ammonialyase (PAL) is the key enzyme. The physical damage of plant tissue can increase PAL activity, which leads to an increase in phenolic compounds (Fan, 2005). Therefore, increasing in phenolic content may be due to a stress induced in these samples after certain time interval.

Flavonoids are phenolic derivatives and found in substantial amounts in grapes. The changing pattern of flavonoid in grapes during storage are shown in Table 3.3 and Figure 3.3. The decrease in flavonoid was observed in uncoated grapes and T1 coated samples whereas it increased approx. by 12% - 19% for T2, T3, T6 and T7 coated samples and 37% - 42% for T4 and T5 samples. The flavonoids such as quercetin and catechin are common PPO substrates (Nagai and Suzuki, 2001). It was also reported that quercetin and catechin were oxidized directly by PPO (Jiménez and Garcína-Carmona, 1999). Therefore, the decrease of phenolic composition could be due to the oxidation by PPO (Yamaguchi et al., 2003).

Effect on Antioxidant capacity

Antioxidant capacity was decreased up to 12 days of storage and thereafter increased in all the grapes samples by end of storage (Table 3.4 and Figure 3.3). However the application of *Aloe* gel as edible coating for quality maintenance of grapes help significantly delayed the reduction of antioxidant capacity. During initial days of storage, the decrease in antioxidant capacity may be due to the O_2 -promoted oxidation of the constitutive phenolic compounds and vitamin C (Stewart et al., 1999). The increase in antioxidant capacity after certain time could be attributed to the development of Maillard compounds in line with the development of the brown color (Karadeniz et al., 2000). Enzymatic browning could also contribute to the formation of antioxidant compounds, since an increase in PPO and POD activities has been observed in grapes during postharvest storage (Meng et al., 2008). Phenolic acids (cinnamic and benzoic, esterified or not with tartaric acid) are mainly present in white grapes. These compounds are highly oxidative, producing brown compounds that also show antioxidant activity.

Table 3.4: Effect of *Aloe vera* gel based edible coating on antioxidant activity of grapes

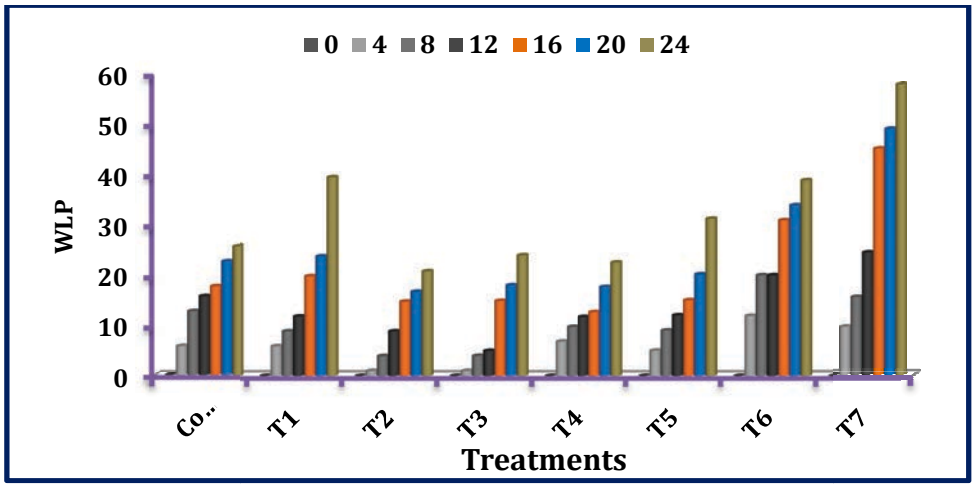
Treatments	Storage period (Days)						
	Antioxidant activity						
	0	**4**	**8**	**12**	**16**	**20**	**24**
Control	95.79±3.64	54.12±1.34	57.78±6.23	94.28±0.27	88.99±1.08	57.94±1.95	0
T1	95.79±3.64	85.56±0.83	51.65±0.65	59.24±1.14	68.58±2.73	73.39±3.01	66.34±1.07
T2	95.79±3.64	85.17±1.75	52.25±0.96	50.14±1.45	75.33±0.95	81.57±2.64	67.58±0.95
T3	95.79±3.64	91.48±0.75	88.81±0.86	62.26±0.91	69.28±1.15	93.04±0.59	72.13±0.90
T4	95.79±3.64	87.05±1.26	74.14±0.67	48.82±1.17	65.53±1.55	69.41±1.26	70.75±1.83
T5	95.79±3.64	84.40±0.86	81.27±0.78	54.69±6.63	73.92±0.79	90.06±0.75	0
T6	95.79±3.64	80.40±1.54	60.38±1.24	83.02±3.06	49.69±1.14	59.68±3.40	68.16±3.22
T7	95.79±3.64	77.38±1.53	67.51±0.12	73.13±1.51	41.59±1.57	85.60±0.52	65.49±1.51

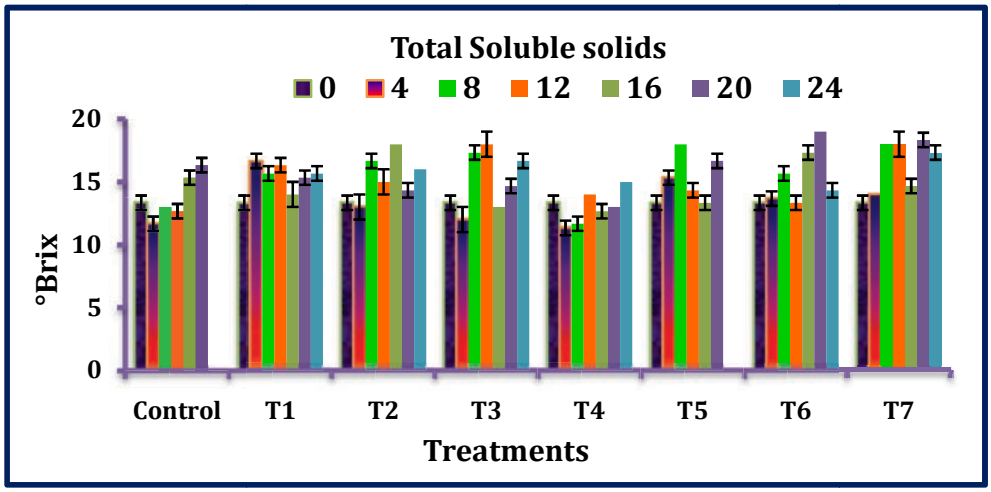
Effect on cell wall softening related enzymes

Softening is an important part of ripening in most fruit during which an increase in water-soluble pectic polysaccharides and the loss of galactose or arabinose from the cell wall occur in many fruits (Huber, 1983; Gross and Sams, 1984) and this is attributed in part to the action of polygalacturonase (PG) and pectin methyl esterase (PME). The data represented in Figure 3.4 indicated the changing behavior the cell wall softening enzymes. The uncoated grapes exhibited consistently declining trend in PG activity during 24 days of storage time. However, the PG activity in coated grapes in the present experiment exhibited declining trend during 12 or 16 days of storage period but thereafter increased with the advance of storage period depending on the applied treatment. The activity of PME was found to be declining in T3 and T4 samples during 24 days of storage time whereas T1, T2, T5, T6 and T7 showed initial reduction during initial 8 days of storage and thereafter increased with the advance of storage time. The result regarding the changing trend of cellulase activity in both coated and uncoated grapes as represented in Figure 3.4, showed that it raised to its peak value on 4^{th} day of storage and thereafter declined towards the end of the storage time. The highest increment was noticed in control, T1 and T7 samples on 4^{th} day of storage. However, this increment was significantly ($p<0.05$) delayed in T2, T3 and T6 grapes samples throughout the storage period of 24 days.

Therefore, the result of the present experiment on the application of *Aloe vera* based edible coating showed that 25% *Aloe vera* (T3) and 10% *Aloe vera* + 0.5% clove oil (T6) posses better efficacy compared to other treatment in maintaining the quality of grapes and extended shelf-life of upto 24 days of storage compared to only 16 days of control grapes.

Figure 3.1: Effect of *Aloe vera* gel based edible coating on weight loss percentage (WLP), TSS and pH of grapes.





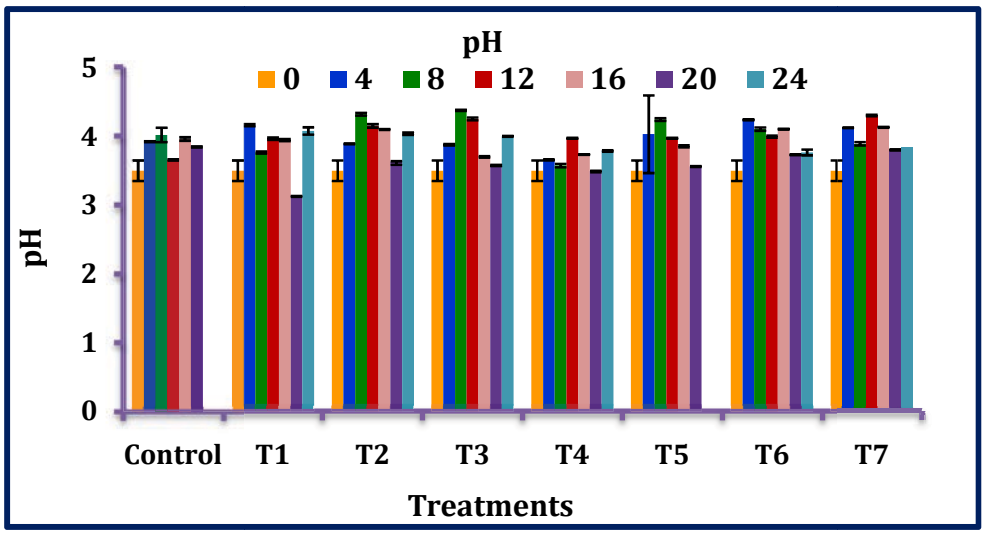
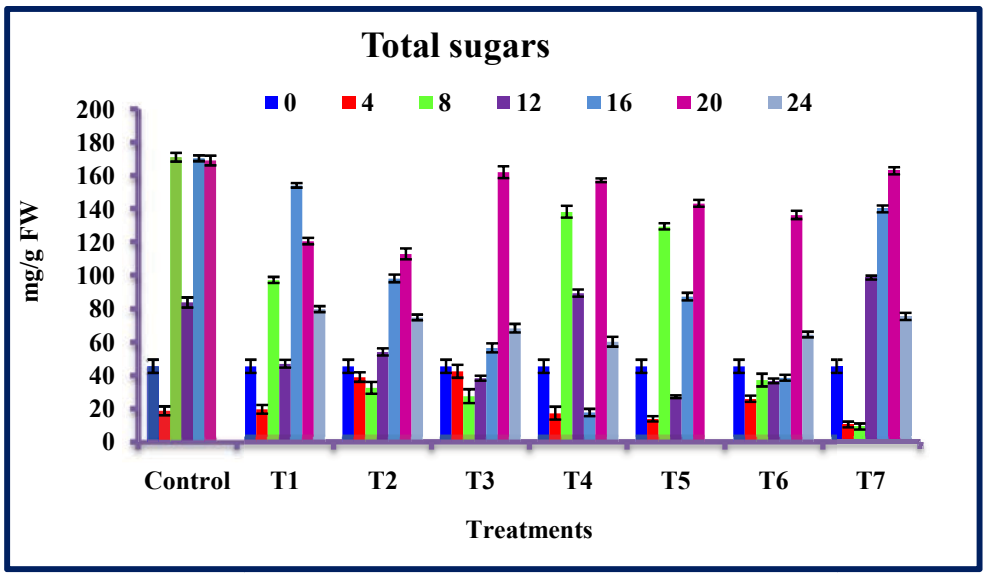


Figure 3.2: Effect of *Aloe vera* gel based edible coating on total sugars and ascorbic acid of grapes.



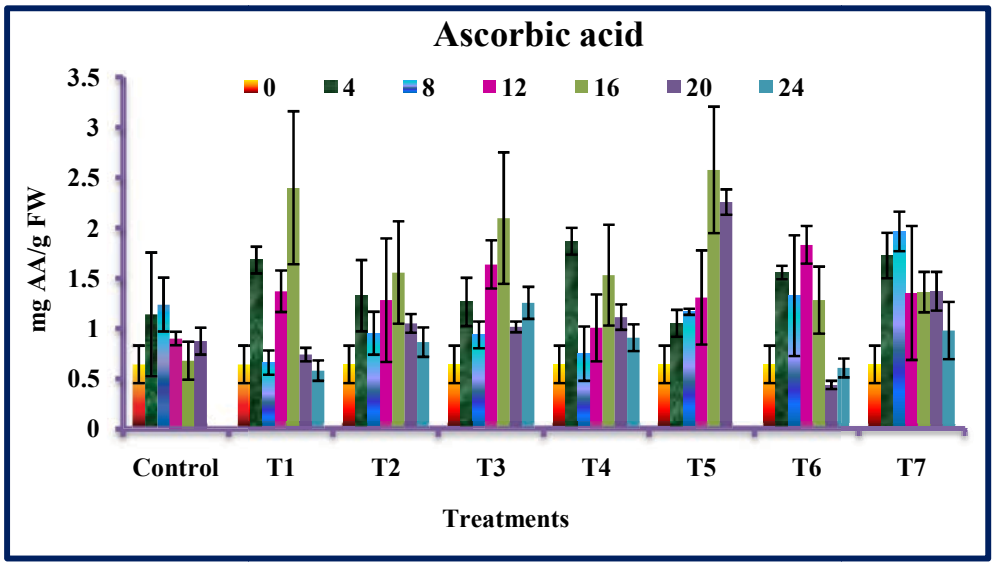


Figure 3.3: Effect of *Aloe vera* gel based edible coating on total phenol, total flavonoids and antioxidant activity of grapes.

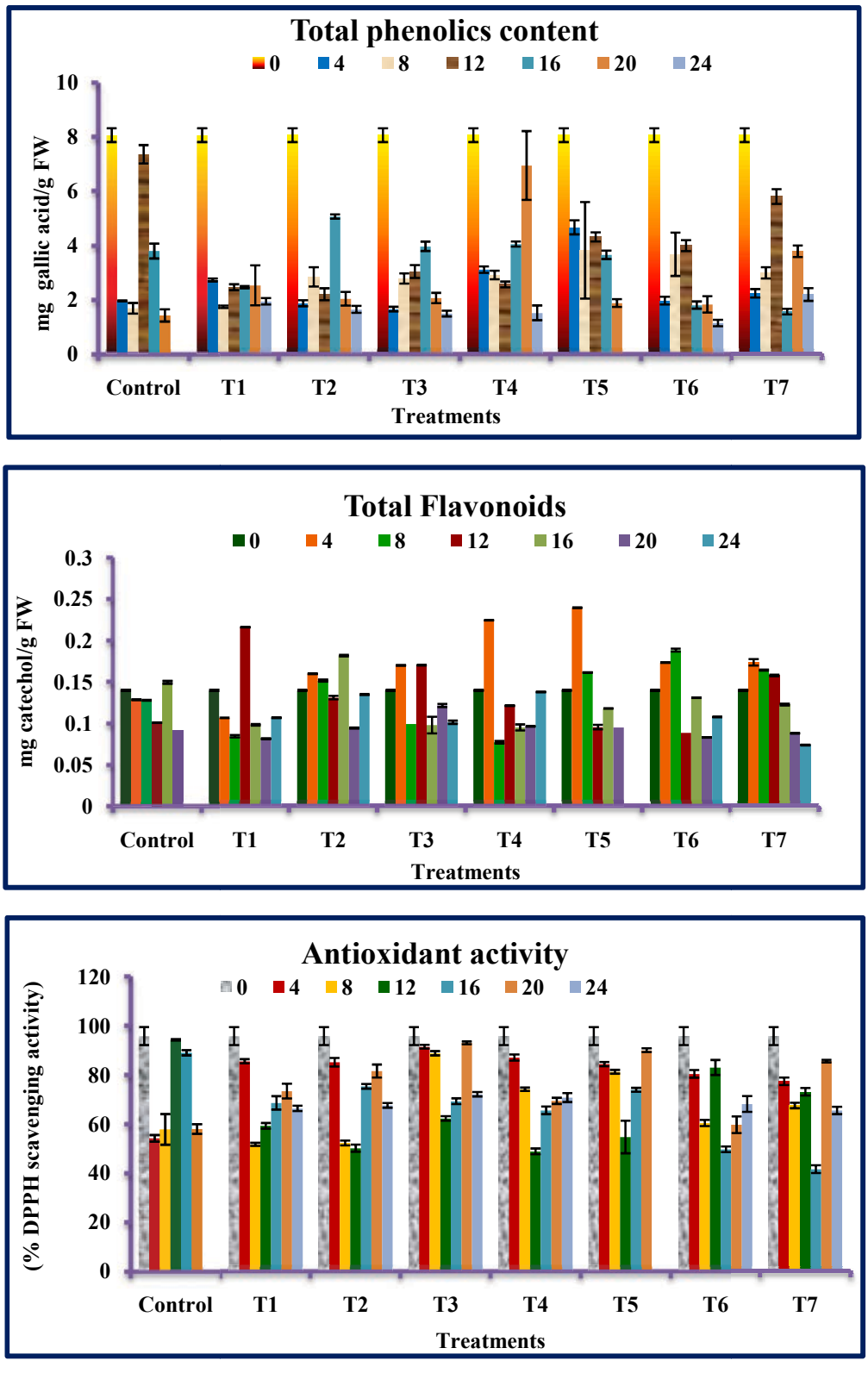


Figure 3.4: Effect of *Aloe vera* gel based edible coating on PG, PME and Cellulase of grapes.

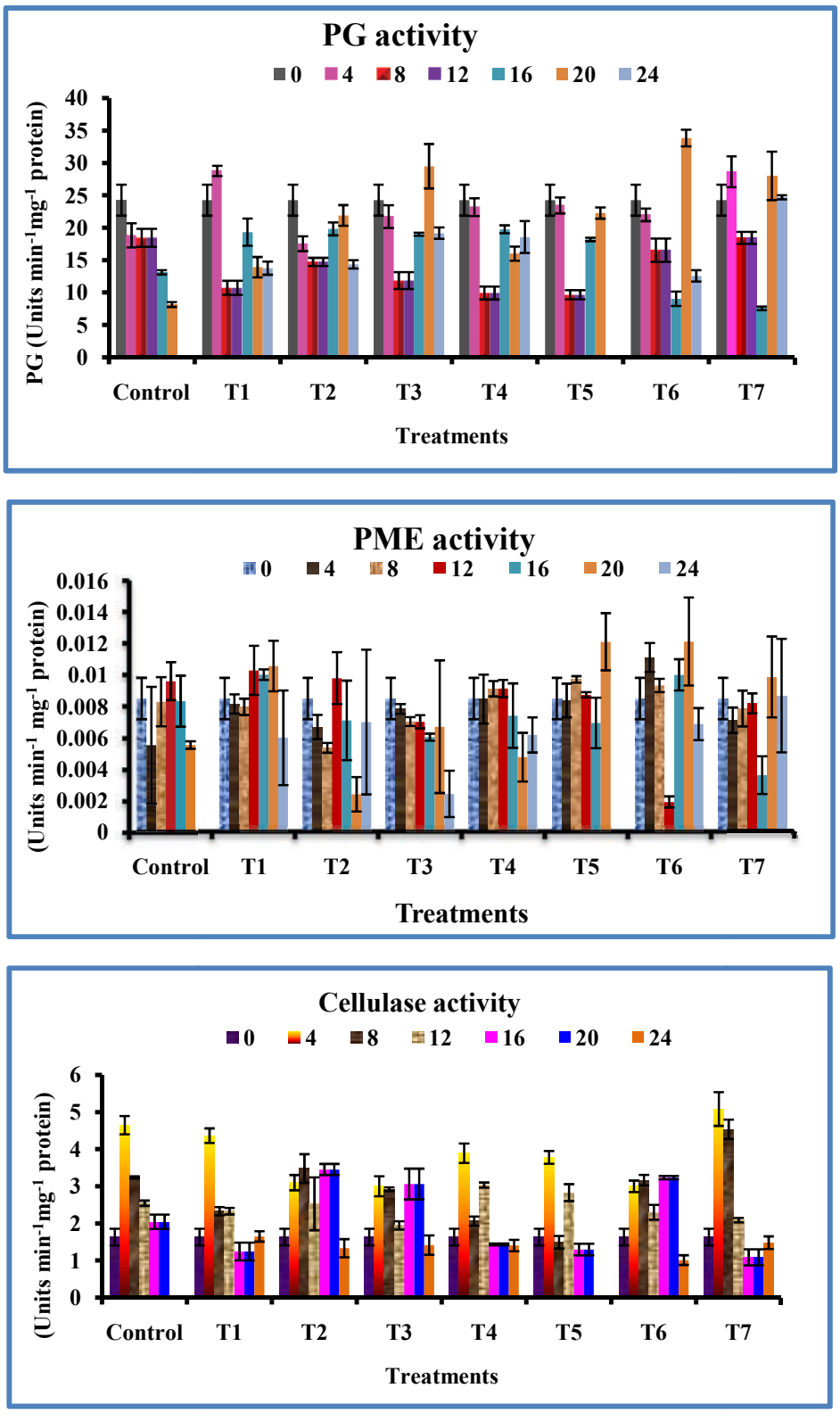


PLATE 3.1

A – Plot of *Aloe vera* plant, Botanical Garden, Sardar Patel University, Vallabh Vidyanagar.

B – Collected leaves of *Aloe vera* kept in water for removing the bitterness.

C – *Aloe vera* leaves were peeled and cut into small pieces.

D – *Aloe vera* gel extracted, filtered and stored in flask until further use.

E – Grapes washed and sanitized with 0.2% sodium hypochlorite solution.

F & G – After drying, grapes were weighed and treated with different concentration of *Aloe vera* gel.

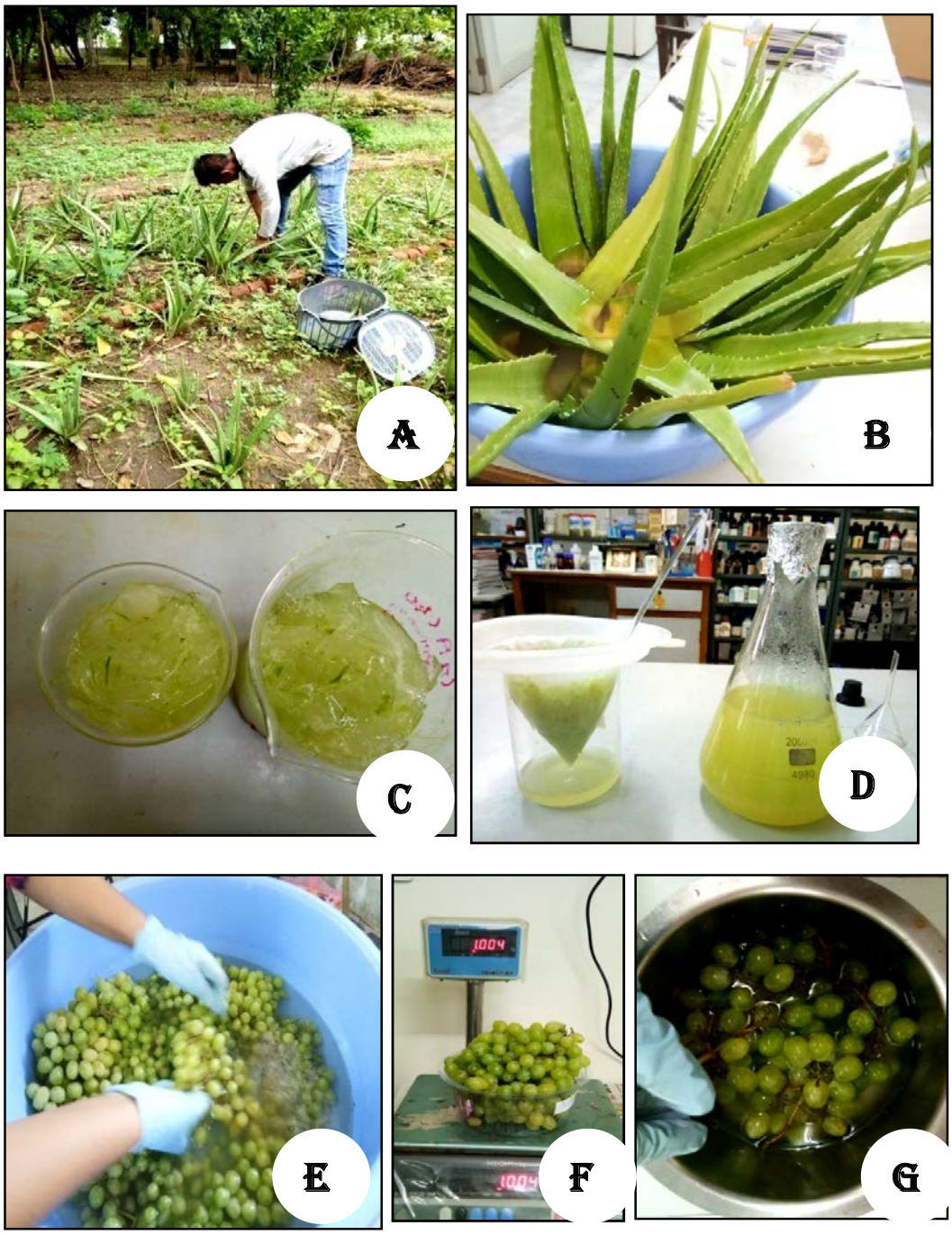


PLATE 3.1

PLATE 3.2

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 8th day of storage (Left column – Treated fruit and Right column – Discarded fruit of corresponding treatments).

C - Control

T1 – 5% *Aloe vera* gel

T2 – 10% *Aloe vera* gel

T3 – 25% *Aloe vera* gel

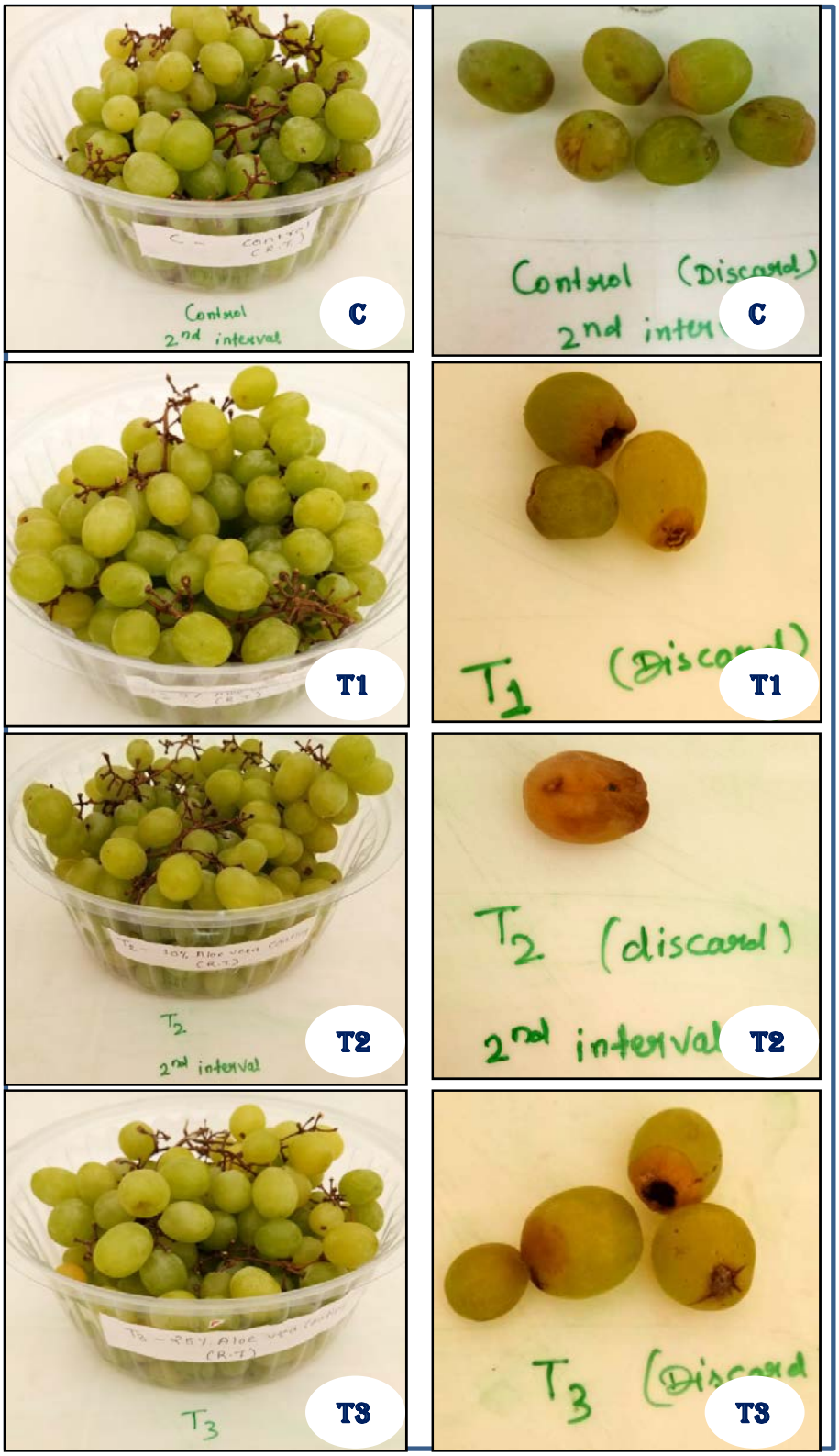

Control
2nd interval
C
Control (Discard)
2nd inter
C
T1
T1
(Discard)
T1
T2
T2
2nd interval
T2 (discard)
2nd interval
T2
T3
T3
T3 (Discard

PLATE 3.2

PLATE 3.3

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 8th day of storage. (Left column – Treated fruit and Right column – Discarded fruit of corresponding treatments)

T4 – 50% *Aloe vera* gel

T5 - 100% *Aloe vera* gel

T6 - 10% *Aloe vera* gel ± 0.5% clove oil

T7 - 10% *Aloe vera* gel ± 1% clove oil

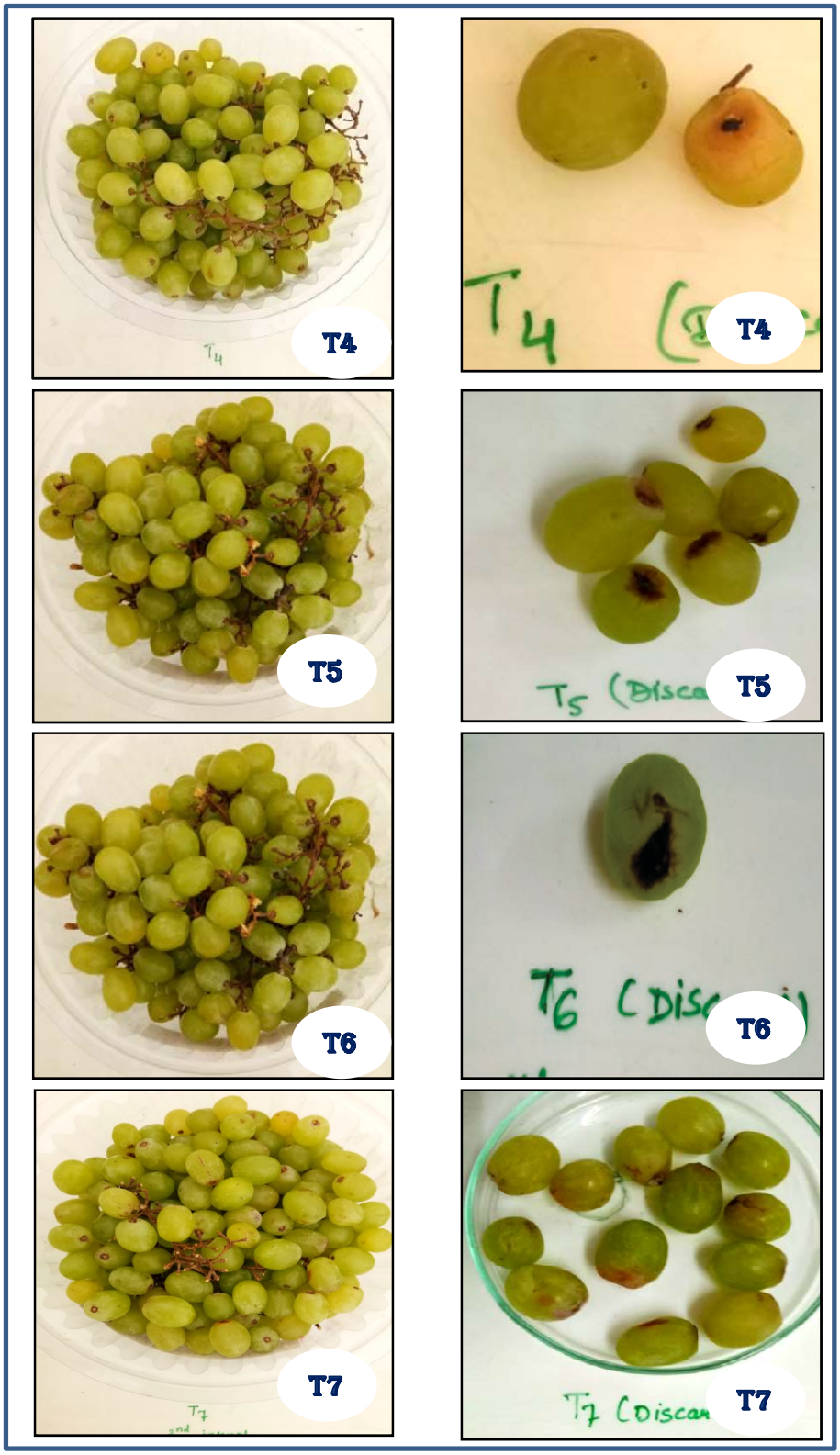


PLATE 3.3

PLATE 3.4

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 16th day of storage (Left column – Treated fruit and Right column – Discarded fruit of corresponding treatments).

C - Control

T1 – 5% *Aloe vera* gel

T2 – 10% *Aloe vera* gel

T3 – 25% *Aloe vera* gel

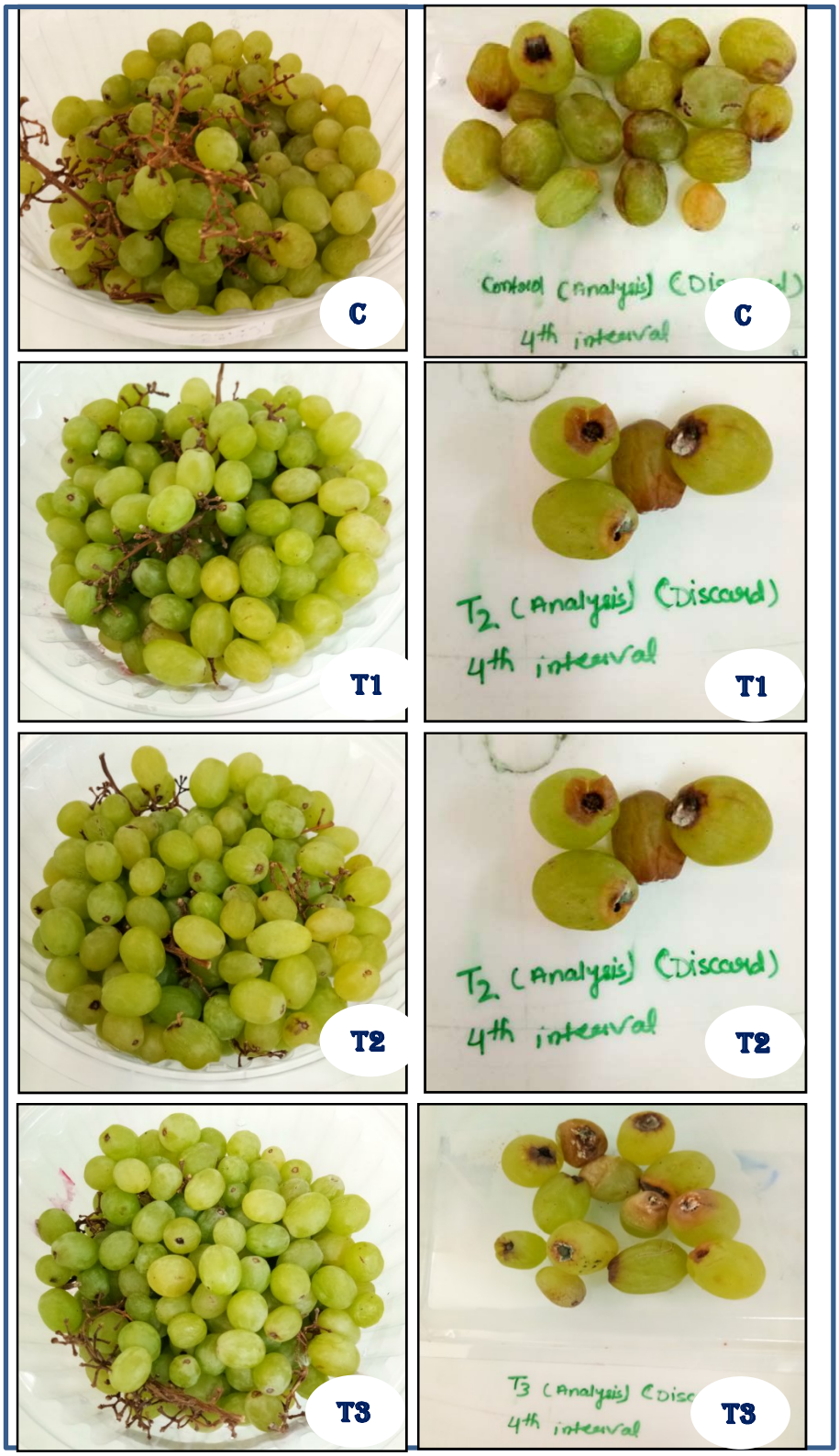

C
C
4th interval
T1
T2 (Analysis) (Discard)
4th interval
T1
T2
T2 (Analysis) (Discard)
4th interval
T2
T3
4th interval
T3

PLATE 3.4

PLATE 3.5

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 16th day of storage. (Left column – Treated fruit and Right column – Discarded fruit of corresponding treatments)

T4 – 50% *Aloe vera* gel

T5 - 100% *Aloe vera* gel

T6 - 10% *Aloe vera* gel ± 0.5% clove oil

T7 - 10% *Aloe vera* gel ± 1% clove oil

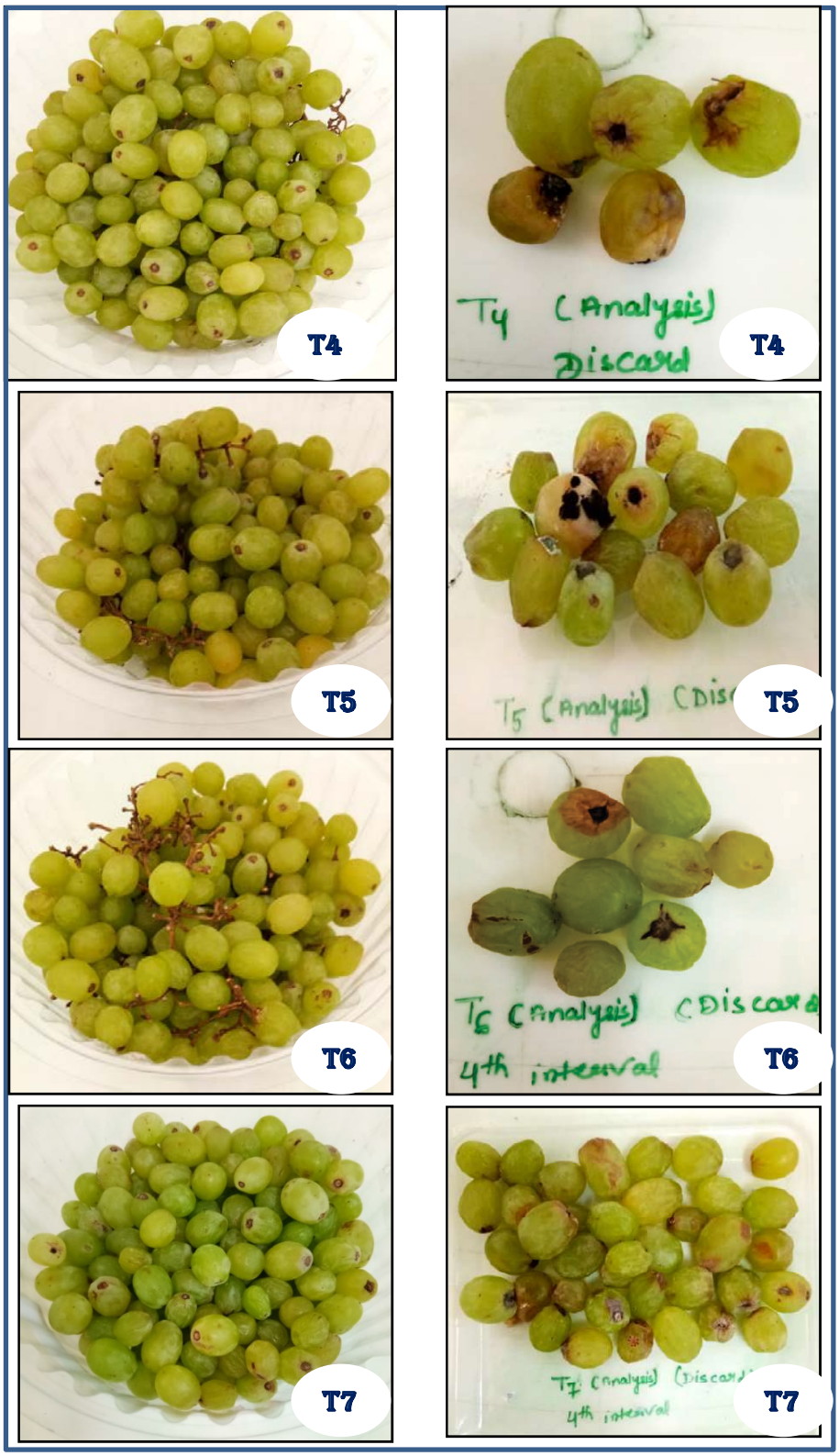

T4
T4 (Analysis)
Discard
T4
T5
T5 (Analysis)
T5
T6
T6 (Analysis)
4th interval
T6
T7
T7 (Analysis)
4th interval
T7

PLATE 3.5

PLATE 3.6

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 20th day of storage. (Left column – Treated fruit and Right column – Discarded fruit of corresponding treatments).

C - Control

T1 – 5% *Aloe vera* gel

T2 – 10% *Aloe vera* gel

T3 – 25% *Aloe vera* gel

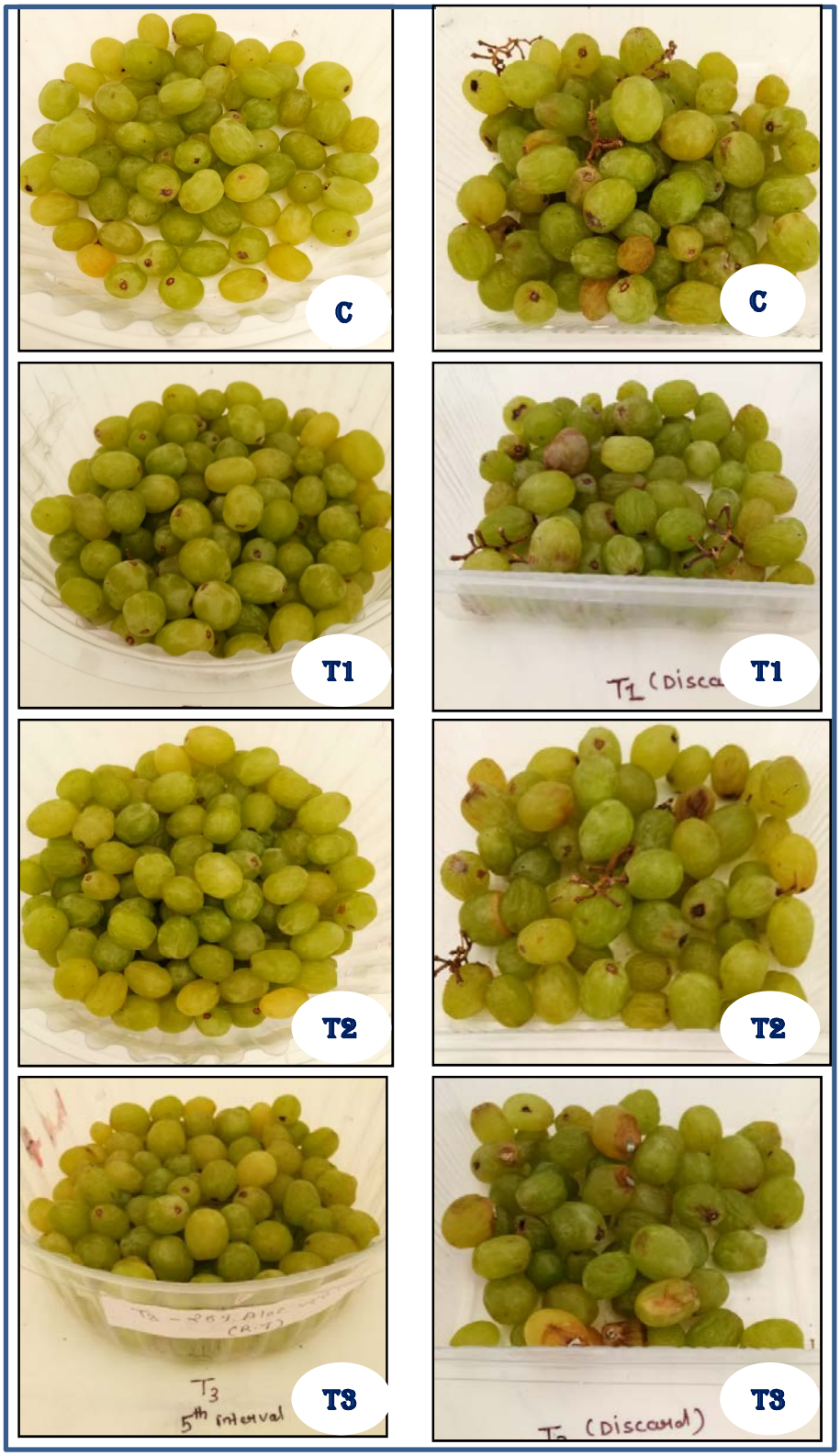


PLATE 3.6

PLATE 3.7

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 20th day of storage. (Left column – Treated fruit and Right column – Discarded fruit of corresponding treatments)

T4 – 50% *Aloe vera* gel

T5 - 100% *Aloe vera* gel

T6 - 10% *Aloe vera* gel ± 0.5% clove oil

T7 - 10% *Aloe vera* gel ± 1% clove oil

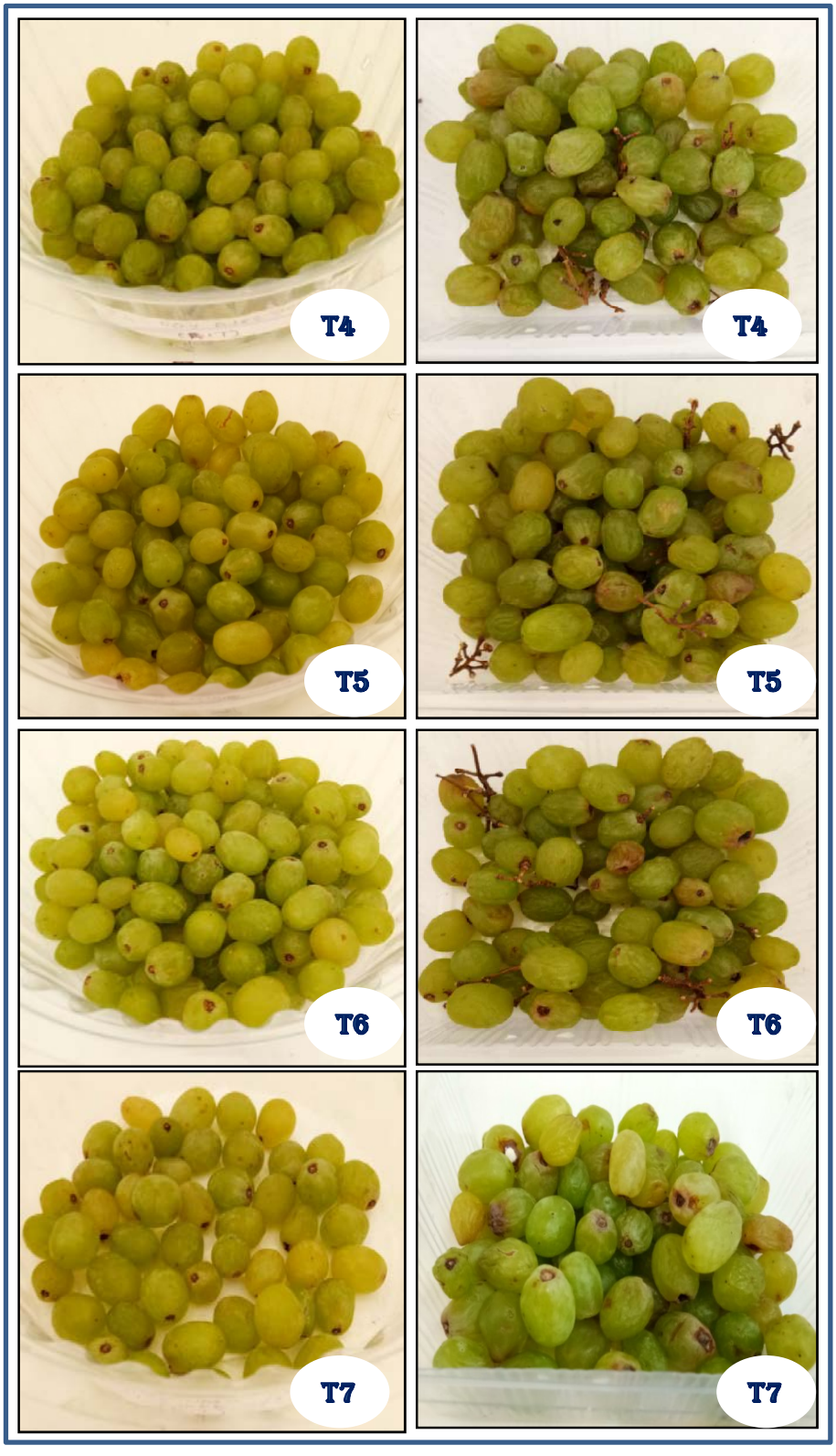


PLATE 3.7

PLATE 3.8

Effect of *Aloe vera* gel based edible coatings on visual quality of grapes on 24th day of storage.

C - Control

T1 – 5% *Aloe vera* gel

T2 – 10% *Aloe vera* gel

T3 – 25% *Aloe vera* gel

T4 – 50% *Aloe vera* gel

T5 - 100% *Aloe vera* gel

T6 - 10% *Aloe vera* gel ± 0.5% clove oil

T7 - 10% *Aloe vera* gel ± 1% clove oil

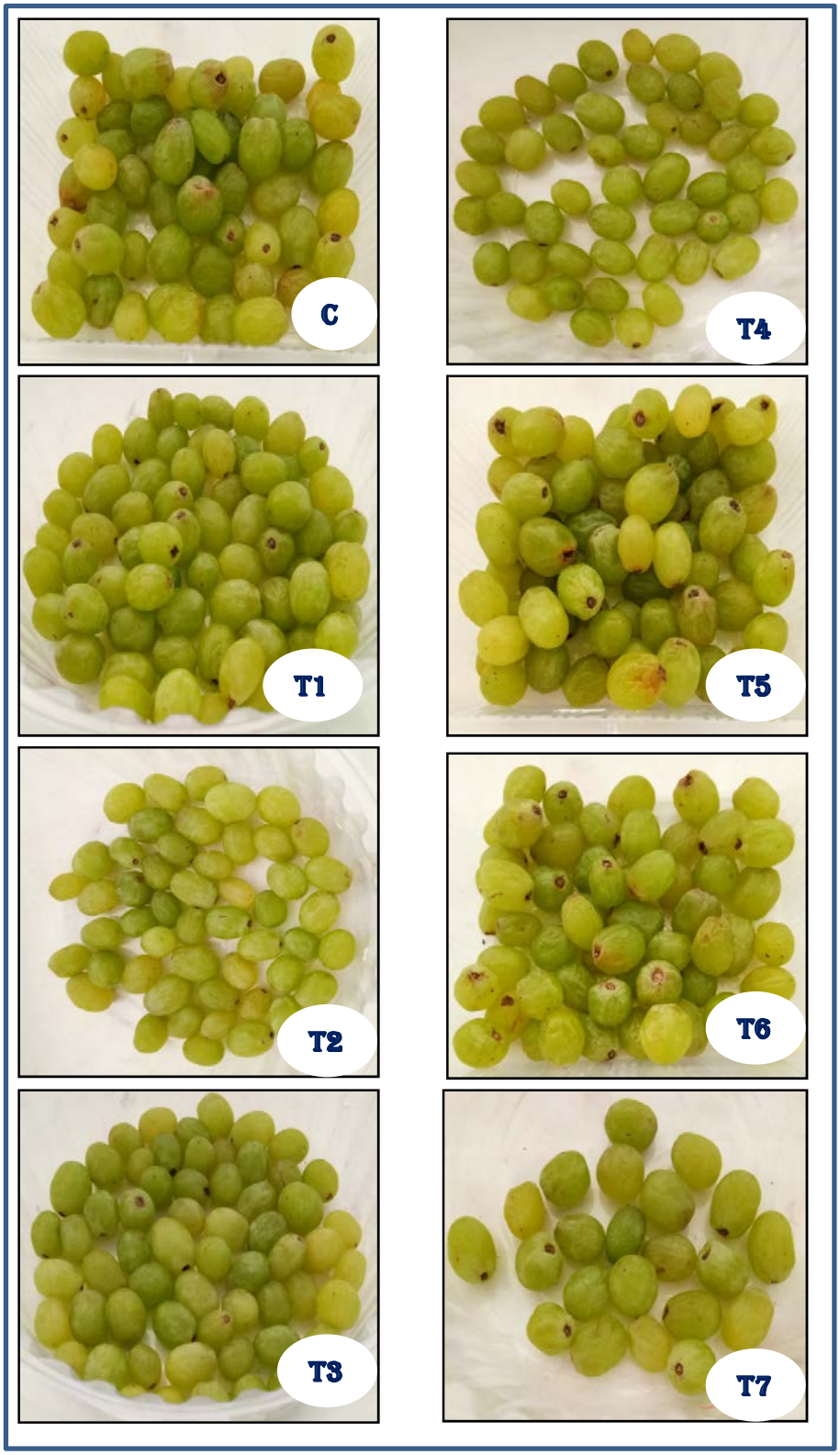


PLATE 3.8

4. Jamun (*Syzygium cumini* L.)

Introduction:

Jamun (*Syzygium cumini* L.), belongs to the Myrtaceae family, is an underutilized fruit from the Indian subcontinent. Its fruits are available abundantly during the summer season for a short period. The fruits are deep purple or bluish in color with pinkish pulp, It is a rich source of anthocyanins including delphinidin, cyanidin, petunidin, malvidin-glucoside which are responsible for the deep purple color and other component like vitamin C, gallic acid, tannins (Banerjee et al., 2005). It is also used for the treatment of various diseases as an astringent, antiscorbutic, diuretic, antidiabetic, and in chronic diarrhea and enlargement of the spleen (Achrekar et al., 1991; Chaturvedi et al., 2009). These beneficial effects are mostly due to the presence of bioactive compounds, such as pigments and phenolic compounds. Jamun is luscious when consumed fresh with salt. However, its seasonal availability with high perishability have raised the need for the preservation of jamun using eco-friendly viable technology.

Collection of fruit and application of treatments

The freshly harvested jamun fruits were immediately transported to the laboratory, and they were sorted for their uniform shape, size, and maturity and with no signs of mechanical damage or microbial decay. Jamun fruit were cleaned by washing them in water and then immersed in 2% solution of sodium hypochlorite (NaOCl) for 10 minutes and air dried at room temperature. These fruits were grouped into four sets having three units in each set. Of these, four sets were kept as experimental sets, while the fifth was treated as control set. And subsequently they were subjected to the following edible coating treatments by dipping for 2-3 min: (1) T1 - 0.5% *Aloe* gel, (2) T2 – 1.0% *Aloe* gel, (3) T3 – Ozone water (200mg/hr), (4) T4 – Ozone water (200mg/hr) + 0.5% *Aloe* gel, (5) T5 - Ozone water (200mg/hr) +1.0% *Aloe* gel. Following these treatments, all the sets were kept to air dry at room temperature and stored at 10±2°C. These stored fruits were subjected to their physicochemical and biochemical analyses at 0, 3, 6 and 9 days of storage.

Results:

Effect on Weight loss percentage (WLP)

The result regarding the WLP of uncoated and coated jamun indicated that the WLP of uncoated fruit was significantly higher than that of coated fruit throughout the storage period of 9 days at 10°C (Table 4.1 and Figure 4.1). WLP in control samples was increased from 10% on 3rd day of storage to 89% on 9th day of storage while treated samples observed with comparatively lesser WLP that ranged between 51% - 61% by the end of storage period. Among the treatments applied, 1% *Aloe*-treated alone showed least WLP (43%) at 9th day of storage followed by ozone water treated jamun e.g. 46%. Weight loss of fruit was mainly associated with respiration and moisture evaporation through the skin by vapor pressure, which can cause flesh softening, fruit ripening, and senescence by metabolic reactions (Park, 1999). In the present study, the reduction in weight loss could be attributed to the semi permeable barrier created by the edible coatings, which in turn reduced respiration, water loss, and oxidation reactions.

Table 4.1: Effect of *Aloe vera* gel based edible coating and ozone water on weight loss percentage (WLP) of jamun.

Treatments	Storage period (Days)			
	Weight loss percentage			
	0	**3**	**6**	**9**
Control	0	10±0	12.0±0	89.0±0
T1	0	0	1.0±0	61.0±0
T2	0	1.0±0	2.0±0	43.0±0
T3	0	0	3.0±0	46.0±0
T4	0	0	1.0±0	51.0±0
T5	0	2.0±0	22.0±0	51.0±0

Effect on TSS and pH

The TSS of jamun fruit initially was 8.67±0.58 % which was increased to 11.0±1.0% on day 3 of storage and thereafter gradually declining with extend of storage time in control set. As shown in Table 4.1 and Figure 4.1, the trend of TSS change is varying among treated jamun fruit. The TSS content of 0.5% and 1.0% *Aloe*-treated and ozone water treated jamun gradually declining up to 6th day of storage but thereafter

raised suddenly at the end of storage time. Jamun fruit treated with Ozone water treatment in combination with 0.5% *Aloe* gel showed gradual rise in TSS content up to 6 days of storage but declined to 8.33±0.58 at the end of storage. These results indicated that among the treatments applied, 1.0% *Aloe*-gel treated jamun fruit showed lesser fluctuation in TSS content throughout the storage time. As the storage time increases, the rise or fall of TSS content noticed in the present study indicated that control jamun fruit exhibited faster metabolic change as TSS increased on 3rd days while such increment in TSS was delayed in treated jamun fruit and observed after 6 days of storage.

The value of pH in treated and untreated jamun was noted to be fluctuating throughout storage as represented in Table 4.2 and Figure 4.1. At 0 day of storage, the pH was 3.61±0.01 which increased in uncoated jamun fruit to 3.79±0.01 by the end of storage time. However, treated samples though exhibited fluctuating pattern during storage period of 9 days but the values remained lower as compared to that of untreated jamun. Similar results were also reported by Gol et al. (2015) in jamun fruit.

Effect on Total sugars

The fresh jamun contains 42.01±5.49 mg/g FW of total sugars, which further increased on 3rd days of storage reaching to its maximum amount i.e. 84.64±9.57 mg/g FW in control set of jamun (Table 4.2 and Figure 4.1). After 3 days of storage, it showed diminishing pattern till 9 days of storage in control samples. Such type of changing behavior in total sugars indicated that during initial days of storage the polysaccharides might have converted to sugars and later utilized in the respiration process (Pandey et al., 2010). The application of *Aloe* gel as edible coating was found effective to certain extend in delaying the ripening process since the increase of total sugars in 0.5% and 1% *Aloe* gel treated jamun was comparatively lesser as compared to uncoated samples. Similarly, ozone water treatment has also played role in maintaining the total sugars content in jamun during 9 days of storage. Interestingly, the application of *Aloe* gel after ozone water treatment of jamun helped retain initial total sugars content throughout the storage period of 9 days at 10°C with least reduction on 3rd and 6th days of storage.

Effect on Ascorbic acid

In general, fruit are naturally recognized by their ascorbic acid (vitamin C) contribution to the diet, and it is also known that as ripening advances, the level of it decreases (Lee and Kader, 2000). Ascorbic acid in jamun fruit at 0 day was 6.89±0.54 mg/g FW. During 9 days of storage time, ascorbic acid declined to 4.14±0.92 mg/g in control samples (Table 4.3 and Figure 4.2). Among the treated jamun fruit, 1% *Aloe* gel exhibited consistently declining trend with advance of storage period, whereas the application of 0.5% *Aloe* gel alone and in combination with ozone water treatment helped retain ascorbic acid content during 9 days of storage period.

Table 4.2: Effect of *Aloe vera* gel based edible coating and ozone water on total soluble solids, pH and total sugars of jamun.

Treatments	Total Soluble Solids			
	0	**3**	**6**	**9**
Control	8.67±0.58	11.0±1.0	9.33±0.58	7.67±0.58
T1	8.67±0.58	8.33±0.58	7.33±0.58	13.00±0.00
T2	8.67±0.58	7.00±0.00	5.00±1.00	7.33±0.58
T3	8.67±0.58	9.33±0.58	7.00±0.00	12.33±0.58
T4	8.67±0.58	10.33±0.58	12.67±0.58	8.33±0.58
T5	8.67±0.58	13.00±0.58	9.00±0.00	11.33±0.58
	pH			
	0	**3**	**6**	**9**
Control	3.61±0.006	3.50±0.015	3.51±0.015	3.80±0.006
T1	3.61±0.006	3.21±0.006	3.38±0.015	3.63±0.006
T2	3.61±0.006	3.23±0.006	3.60±0.01	3.4
T3	3.61±0.006	3.42±0.006	3.46±0.006	3.52±0.006
T4	3.61±0.006	3.24±0.012	3.36±0.006	3.50±0.006
T5	3.61±0.006	3.35±0.006	3.29±0.006	3.53±0.006
	Total sugars			
	0	**3**	**6**	**9**
Control	42.01±5.49	84.64±9.57	51.05±6.97	39.49±5.69
T1	42.01±5.49	60.56±5.35	61.19±9.38	35.15±5.30
T2	42.01±5.49	13.39±7.44	65.87±11.36	62.75±7.57
T3	42.01±5.49	23.49±6.85	44.97±7.27	45.03±6.20
T4	42.01±5.49	36.33±6.50	34.55±5.32	49.16±4.56
T5	42.01146	37.54±7.69	29.22±2.92	51.93±7.72

Effect on Total phenol content and total anthocyanin

The changes in the content of total phenols are shown in Table 4.3 and Figure 4.3. Total initial phenolic content of jamun fruit was 19.69±0.30 mg/g, which increased on 3rd day of storage period in control fruit, 0.5% and 1% *Aloe* gel coated samples. In the control fruit, the increment in their phenolic content was seen only up to 3rd day of storage period and thereafter decline towards the end of storage period, while, in 0.5% and 1% *Aloe* gel coated samples, the increment was noticed on 9th day of storage period with significant reduction on 6th day of storage. The reduction of phenolic content was found up to 6 days of storage in ozone water treated sample and its combination with edible coating increased at the end of storage and maintained higher amount as compared to control samples. These results are in agreement with Gol et al. (2015). After 9 days of storage, control fruit exhibited significantly ($P < 0.05$) a lower level of phenols (13.44±0.29 mg/g), while all of the coated fruit have maintained the higher level of phenolic content in comparison with control. The results represented in Table 4.3 and Figure 4.3 revealed that the concentration of total anthocyanins increased in the control as well as in the coated samples. Nevertheless, in the control samples the increment was noticed up to 3 days of storage period, while coated samples have increment depending upon the applied treatment during storage period of 9 days. The total anthocyanin concentration increased from 6.18±0.03 mg/g at 0 day to 10.11±0.03 mg/g at 3rd day of storage in control jamun fruit, but it declined and reached to 7.44±0.02 at 9th day of storage. During 9 days of storage period, the treatments of jamun fruit with ozone water followed by 0.5% and 1% *Aloe* gel coating showed higher accumulation of total anthocyanins as compared to jamun fruit coated with only *Aloe* gel and ozone water. Among coated jamun fruit, the maximum accumulation was noticed in combination treatment (ozone water+1.0% *Aloe* gel) of jamun fruit, i.e., 9.37±0.03 mg/g. These interpretations suggested that the combined treatment of ozone water and *Aloe* gel have synergistic effect in retention of higher content of anthocyanin through formation of a protective barrier on the surface of fruit and reduce the oxidation of phenolic compounds by minimizing the direct contact with atmospheric oxygen.

Table 4.3: Effect of *Aloe vera* gel based edible coating and ozone water on ascorbic acid, total phenol content and anthocyanin of jamun.

Treatments	Storage period (Days)			
	Ascorbic acid			
	0	3	6	9
Control	6.89±0.54	7.89±0.95	4.87±1.07	4.14±0.92
T1	6.89±0.54	4.33±1.05	7.30±1.14	6.76±1.35
T2	6.89±0.54	6.07±1.43	5.88±1.94	3.44±0.74
T3	6.89±0.54	8.44±1.42	6.19±1.44	8.28±1.10
T4	6.89±0.54	3.35±0.67	9.28±1.61	6.51±0.95
T5	6.89±0.54	4.33±1.04	6.19±1.09	6.67±1.47
	Total phenol content			
	0	3	6	9
Control	19.69±0.30	24.71±0.40	11.16±0.72	13.44±0.29
T1	19.69±0.30	29.36±0.40	13.99±0.96	27.66±0.23
T2	19.69±0.30	29.64±0.23	12.03±1.28	26.05±0.58
T3	19.69±0.30	15.77±0.75	11.68±0.87	18.36±1.44
T4	19.69±0.30	21.10±0.84	8.75±0.88	14.82±0.22
T5	19.69±0.30	9.48±0.26	10.99±0.27	22.06±0.73
	Total anthocyanin			
	0	3	6	9
Control	6.18±0.03	10.11±0.03	7.3±0.02	7.44±0.02
T1	6.18±0.03	3.99±0.02	5.02±0.02	4.30±0.03
T2	6.18±0.03	3.29±0.02	7.47±0.02	4.21±0.07
T3	6.18±0.03	5.49±0.03	4.19±0.02	5.53±0.02
T4	6.18±0.03	4.48±0.02	8.98±0.28	4.30±0.01
T5	6.18±0.03	7.05±0.05	4.85±0.04	9.37±0.03

Effect on Antioxidant activity

The change in antioxidant activity of jamun fruit over the storage time is shown in Table 4.4 and Figure 4.3. The antioxidant activity measured in fresh jamun fruit was 92.79±1.35%. Based on the data, it revealed that the change in antioxidant activity was insignificant in all coated and control jamun fruit throughout the storage time of 9 days.

Table 4.4: Effect of *Aloe vera* gel based edible coating and ozone water on antioxidant activity of jamun.

Treatments	Storage period (Days) Antioxidant activity			
	0	3	6	9
Control	92.79±1.35	93.93±0.89	92.39±0.42	92.54±0.90
T1	92.79±1.35	94.25±0.26	94.21±0.39	92.48±0.87
T2	92.79±1.35	94.61±0.55	93.47±0.55	94.06±0.60
T3	92.79±1.35	92.75±0.73	93.43±0.32	92.64±0.98
T4	92.79±1.35	93.36±1.31	94.38±0.49	94.19±0.38
T5	92.79±1.35	93.09±2.06	93.38±0.82	93.24±0.70

Figure 4.1: Effect of *Aloe vera* gel based edible coating and ozone water on weight loss percentage (WLP), TSS and pH of jamun.

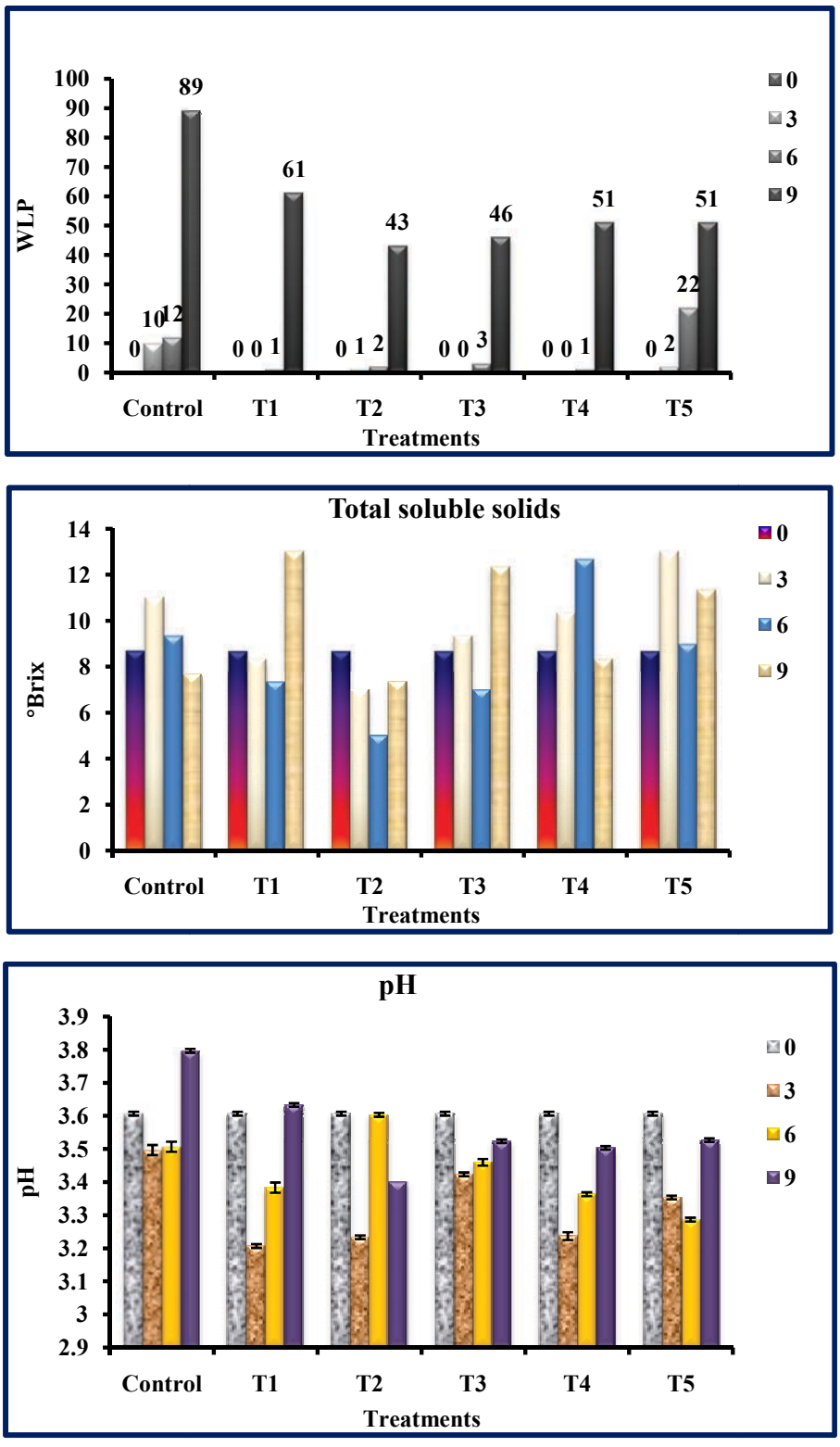
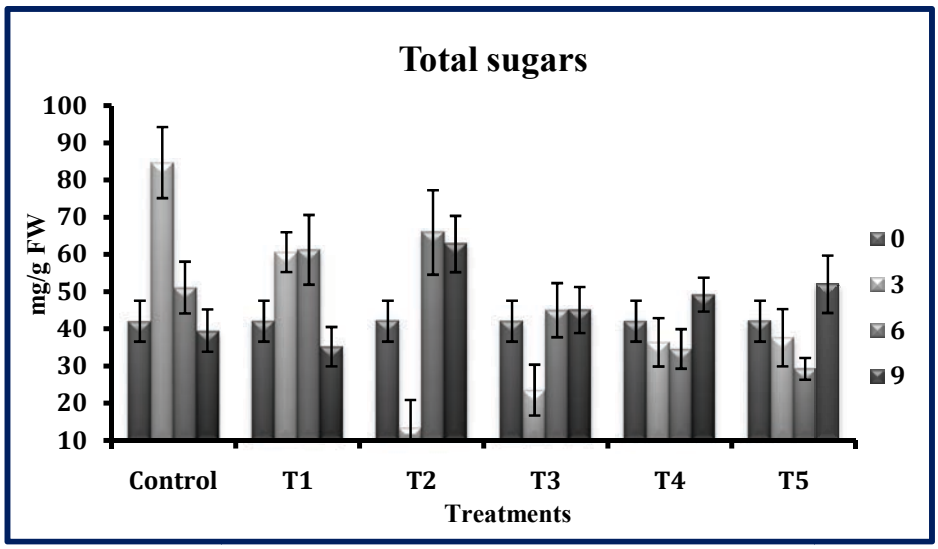


Figure 4.2: Effect of *Aloe vera* gel based edible coating and ozone water on total sugars and ascorbic acid of jamun.



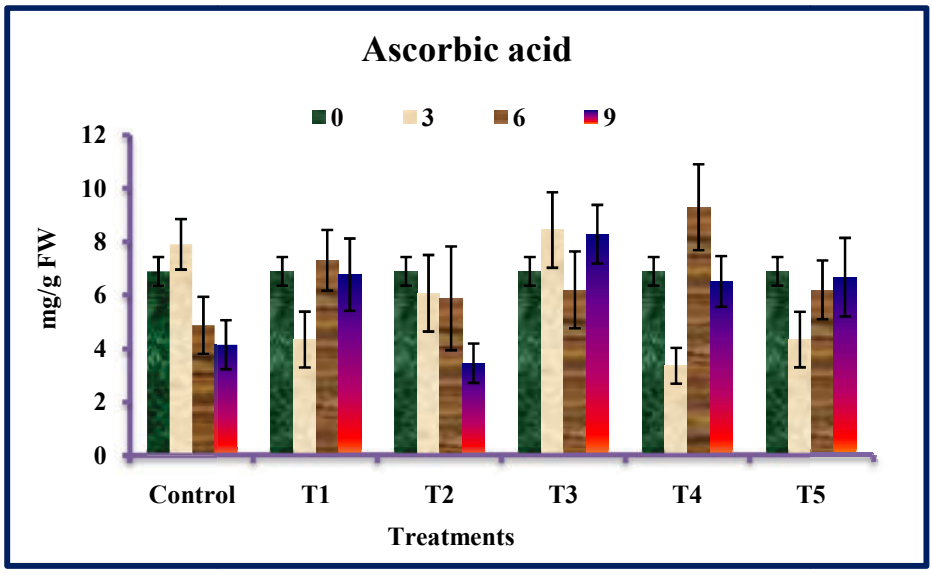


Figure 4.3: Effect of *Aloe vera* gel based edible coating and ozone water on total phenol, anthocyanin and antioxidant activity of jamun.

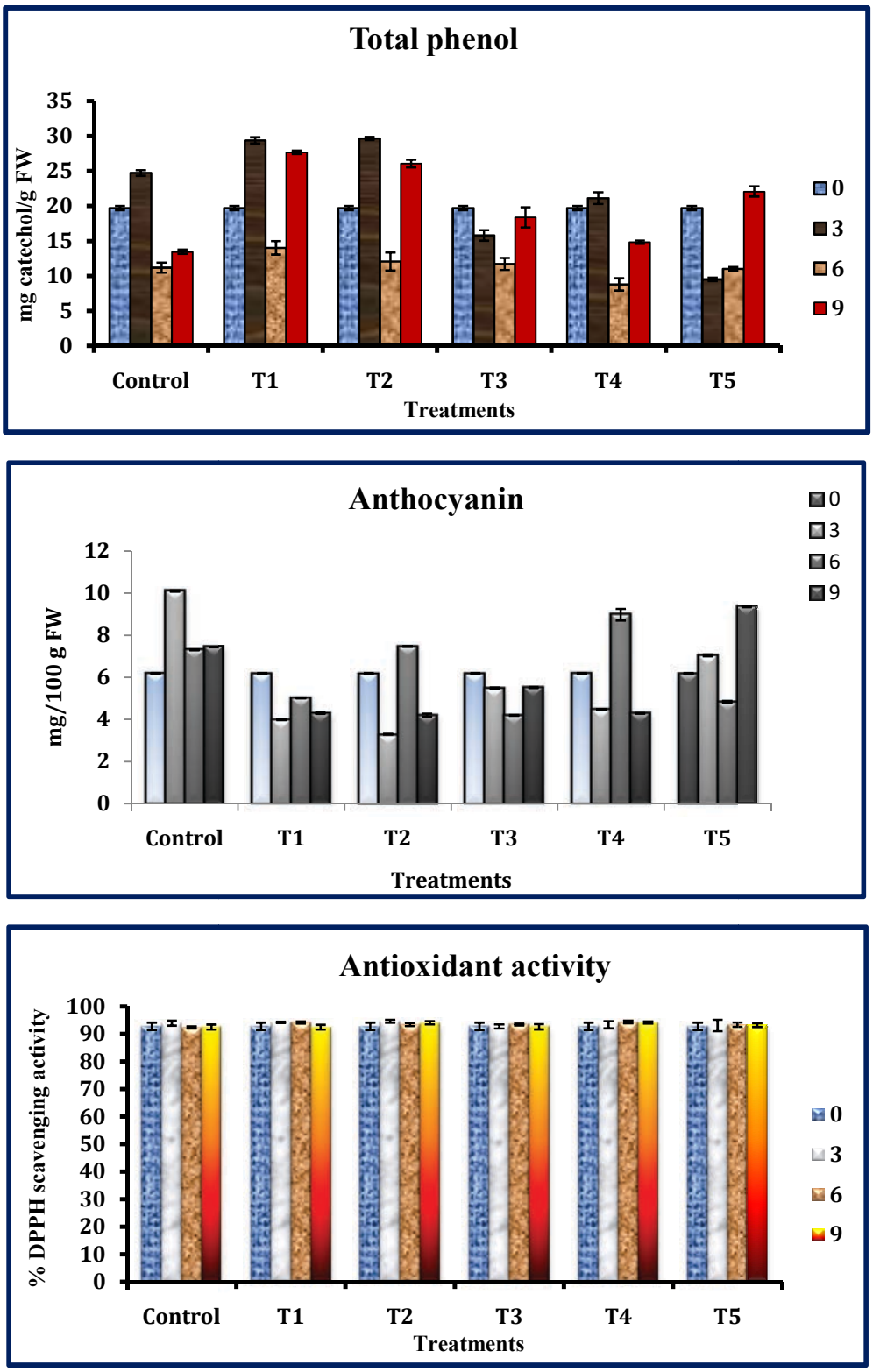


PLATE 4.1

Effect of *Aloe vera* gel based edible coating and ozone water on visual quality of jamun on 3rd day of storage.

C - Control

T1 – 0.5% *Aloe vera* gel

T2 – 1.0% *Aloe vera* gel

T3 – Ozone water (200mg/hr)

T4 – Ozone water (200mg/hr) + 0.5% *Aloe vera* gel

T5 – Ozone water (200mg/hr) + 1.0% *Aloe vera* gel

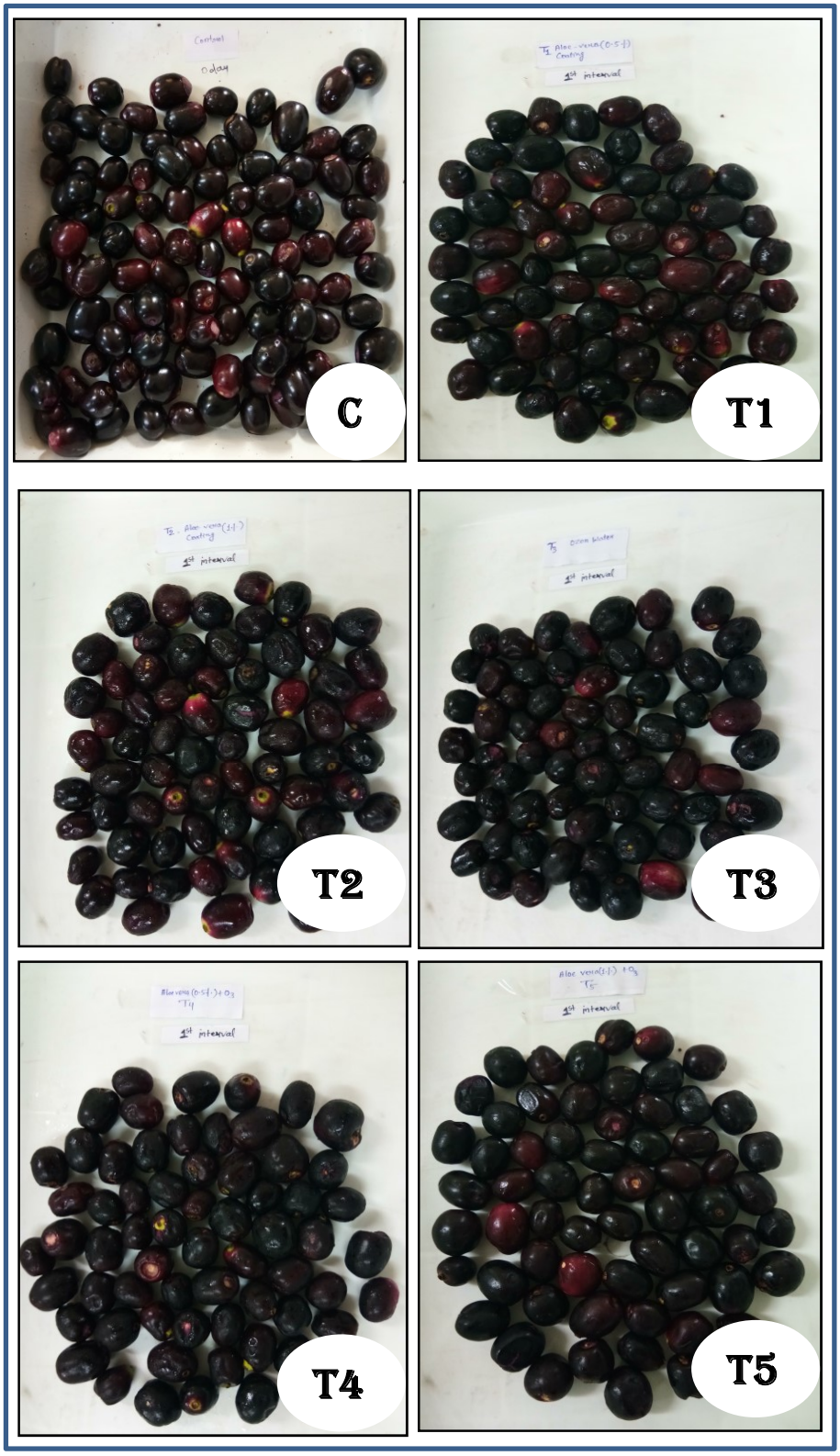


Plate 4.1

PLATE 4.2

Effect of *Aloe vera* gel based edible coating and ozone water on visual quality of jamun on 6th day of storage.

C - Control

T1 – 0.5% *Aloe vera* gel

T2 – 1.0% *Aloe vera* gel

T3 – Ozone water (200mg/hr)

T4 – Ozone water (200mg/hr) + 0.5% *Aloe vera* gel

T5 – Ozone water (200mg/hr) + 1.0% *Aloe vera* gel

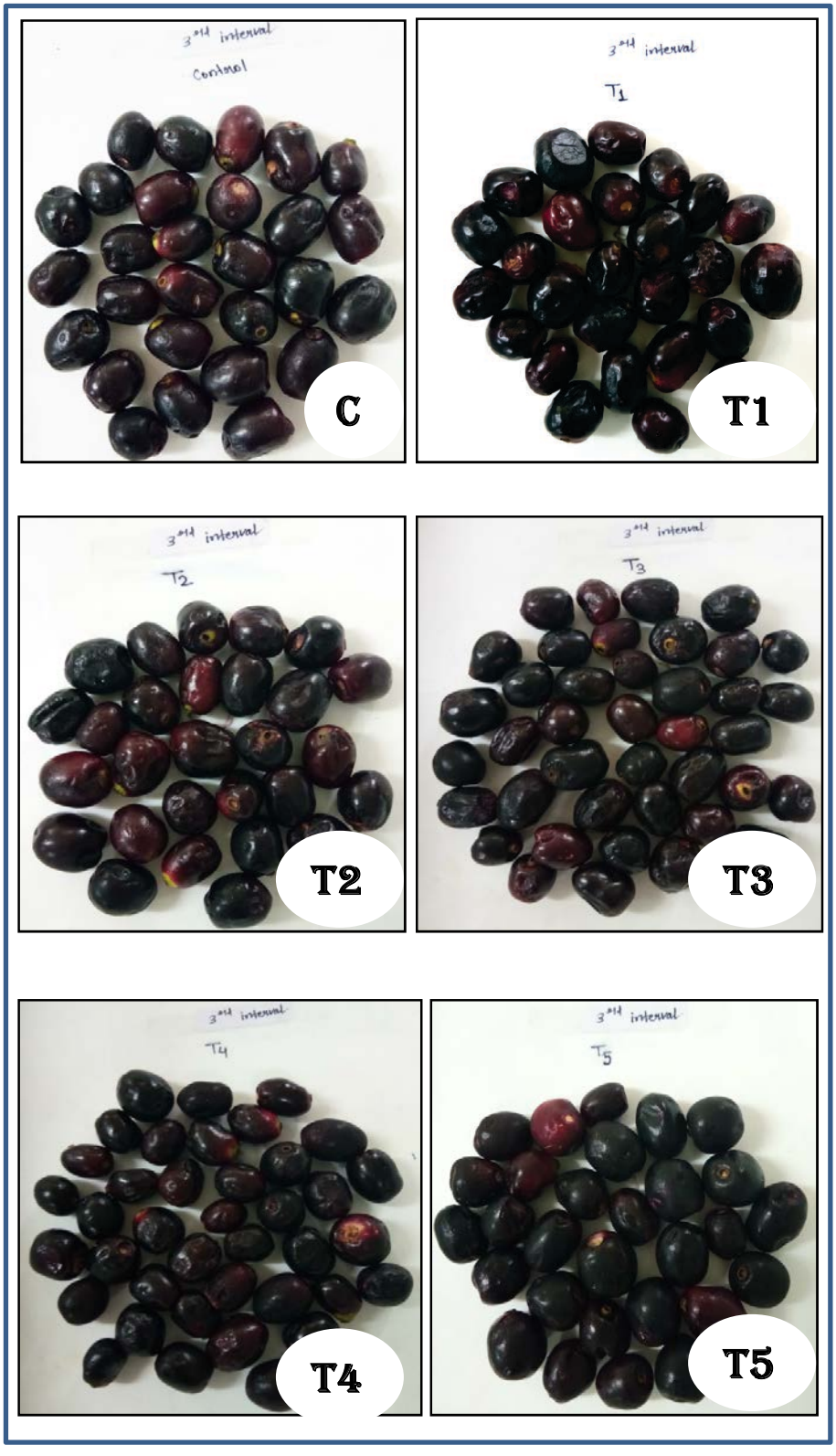

3rd interval
Control
C
3rd interval
T1
T1
3rd interval
T2
T2
3rd interval
T3
T3
3rd interval
T4
T4
3rd interval
T5
T5

Plate 4.2

PLATE 4.3

Effect of *Aloe vera* gel based edible coating and ozone water on visual quality of jamun on 9th day of storage.

C - Control

T1 – 0.5% *Aloe vera* gel

T2 – 1.0% *Aloe vera* gel

T3 – Ozone water (200mg/hr)

T4 – Ozone water (200mg/hr) + 0.5% *Aloe vera* gel

T5 – Ozone water (200mg/hr) + 1.0% *Aloe vera* gel

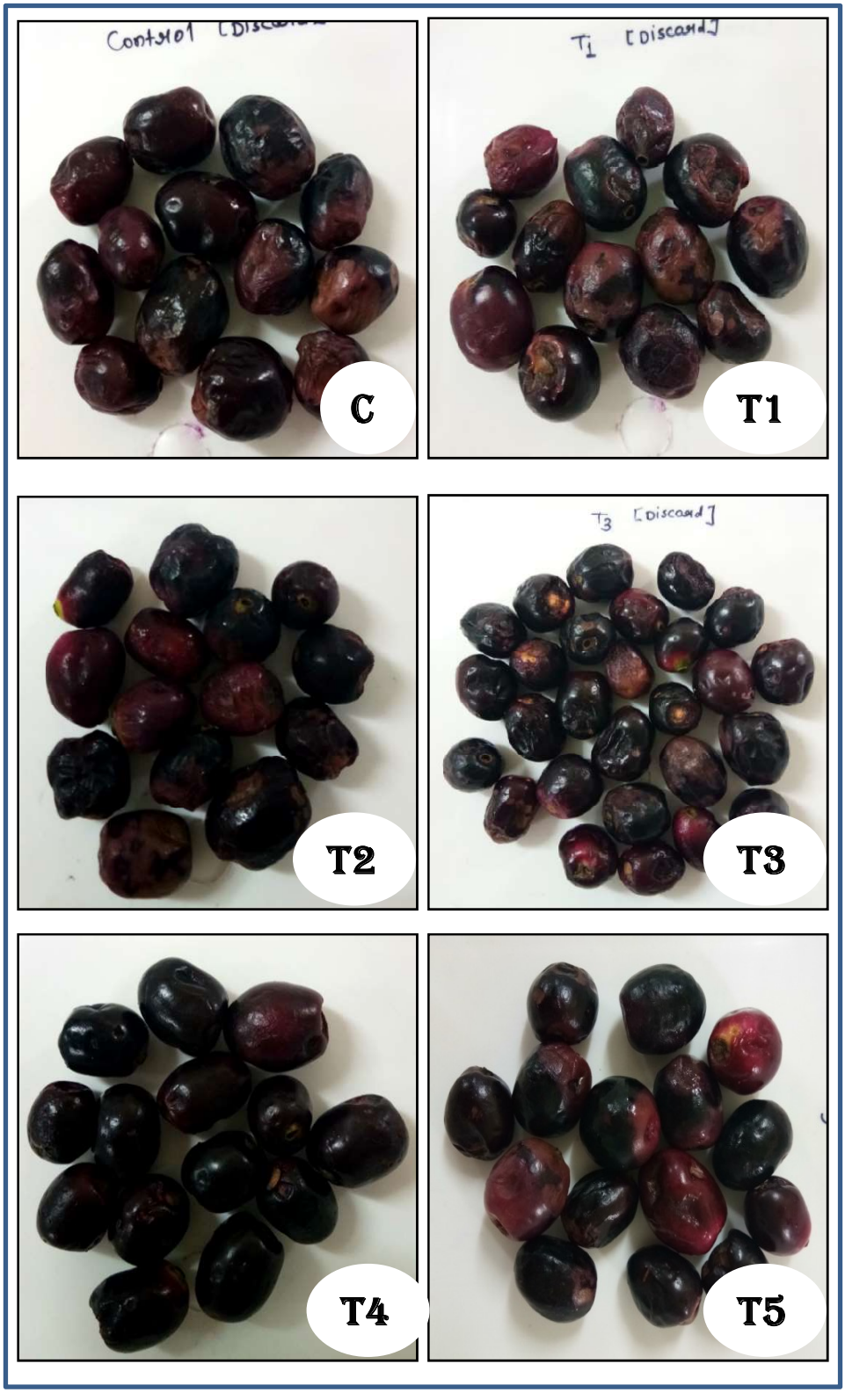


Plate 4.3

5. Mango (*Mangifera indica*)

Introduction:

Mango (*Mangifera indica*) is popularly known as a 'King of fruits', due to its striking taste, rich calorie value and health promoting attributes as well. Mangoes are consumed worldwide therefore it is having a high demand. Mostly mangoes are harvested at their commercial stage, and they are transported to the market with proper packing in the bamboo baskets or wooden baskets (Paliyath et al., 2008). In spite of taking all necessary care, it has a tendency of rapid ripening process after harvesting, massive percentage of good quality fruits getting damaged and eventually they get rotten. To overcome this kind of perishable tendency, some affordable, simple, safe and eco friendly technologies are the need of the hour for reducing the enormous post harvest losses of mango. Therefore, the present study has been undertaken to evaluate the efficacy of physical elicitors like Ozone water and photo sensitizer alone and in combination with edible coating for extending postharvest shelf life of mango.

Collection of mango fruit and application of treatments

The fresh mangoes (*Mangifera indica* cv "Kesar") were harvested at their maturity stage in the month of 'May 2018' from an orchard located in the 'Saniya Kanade' village of Surat district, South Gujarat, India. On upon bringing these fruits to the laboratory, they were graded for their uniform size, shape and without any mechanical injury, washed them with tap water, and subsequently they were treated with 2% sodium hypochlorite for five minutes, then again washed them with tap water so as to remove the residues of sodium hypochlorite, and lastly they were air dried at room temperature. The mangoes were grouped into five sets with 15 fruits in each set. Following this, fruits were treated with seven treatments viz.:(1) T1- Photosensitizer + 5% Gum acacia, (2) T2 - 5% Gum acacia + 0.05% clove oil, (3) T3 - 5% Gum acacia coating alone, (4) T4 - Ozone water + 5% Gum acacia, (5) C - Control. From each set 2 fruits were used for analysis at each interval of 5 days.

Effect on Weight loss percentage:

Freshly harvested mango fruits contain large amount of moisture content and as the ripening process takes place the respiration accelerates. The moisture content looses very quickly through the peel in the form of vapor, so that ultimately there is continuous decreasing weight of the fruit. Eventually the water goes out from the fruit, sometimes shrinkages also can be observed on the fruit surface (Baraiya et al., 2014). The control fruit showed progressive increase in WLP over the entire storage period and with maximum WLP (58.12%) on 15th day of storage. Among the coated fruit, the WLP was significantly lesser in T1, T2 and T4 sets as compared to T3 set during storage period of 30 days. The WLP on 20th day was found to be least in T1 (11.02%) followed by T2 (17.09%) and T4 (21.72%), while in fruits kept in control showed 38.04%. Thereafter, the WLP was increased in coated as well as uncoated fruit and also control fruit were discarded after 20 days of storage time due to decay. The percentage of weight loss in all the fruits treated as well as in control showed in Table 5.1 and Figure 5.1.

Table 5.1: Effect of physical elicitors and gum acacia on weight loss percentage of mango during their storage.

Treatments	Storage period (Days)						
	Weight loss percentage						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	0	3.05741	7.519625	7.431124	11.01995	42.01772	48.89305
T2	0	3.792549	6.407578	7.813663	17.09719	55.50146	55.14223
T3	0	3.066324	6.479933	7.569662	41.70563	46.18363	100
T4	0	2.802242	7.386052	6.907797	21.71975	56.2856	55.46766
C	0	3.344576	7.473103	58.12382	38.04878	100	100

Effect on Total Soluble Solids and pH

The result regarding the changing trend of TSS in all coated and control mango fruit is shown in Table 5.2 and Figure 5.1. TSS recorded in freshly harvested mango fruits was 1.7°Brix. On 5th day of storage period, there was no significant difference found within treated fruits. The TSS measured in T4 was 1.2°Brix while in control it was

recorded 1.6°Brix. On 15th day of storage the TSS of T4 treated samples was 1.5°Brix which was least compared to the other treated mango samples as well as uncoated samples. At 20th day T1, T3 and T4 showed 1.4°Brix, 1.5°Brix and 1.6°Brix which was not significantly different, while in control the TSS observed was 2.2°Brix which was significantly different than any other treatment. On 25th day of storage the TSS was seen in T3 and T4 was 1.6°Brix and 1.8°Brix respectively and in T1 and T2 showed 1.8°Brix and 1.9°Brix respectively. On 30th day of storage period the TSS noticed in T4 was 1.9°Brix and on other hand TSS noticed in T4 was 2.2°Brix which was significantly different.

Mango fruits treated with the combination of ozone water (200mg/hr) and 5% gum acacia showed the significant difference in storage period of postharvest mangoes. The pH increased in all treated and untreated fruits but the rate of increase is slower in treated fruits than that of the control fruits (Table 5.2 and Figure 5.1). At 0 day there was no significant difference ($p \leq 0.05$) between the treatments. The initial pH was 4.02. On day 5, fruit treated with T4 (ozone water and 5% gum acacia) showed 3.92, while control showed pH value of 4.45 which was significantly lower than that of control. On day 10th, fruits treated with T4, T1 and T2 showed 4.7, 4.3 and 4.2 of pH, while control showed 5.6, which was significantly higher than that of other treated fruits. On 15th day the highest readings were recorded in T1 while sudden decrease of pH was recorded in control. On 20th day the highest pH was recorded in T2 i.e. 4.4 and lowest pH was recorded in T1 i.e. 5.6. The fruits treated with T4 showed lowest pH i.e 5.7; on other hand T1 showed pH 6.4 which was significantly higher than that of T4. At the end of storage period the pH in T4 was recorded 6.6 while in T1 showed 6.9, which was significantly higher than that of T4.

Table 5.2: Effect of physical elicitors and gum acacia on total soluble solids and pH of mango during their storage.

Treatments	Storage period (Days)						
	Total soluble solids						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	1.7±0.1	1.27±0.15	1.6±0.1	1.80±0.1	1.47±0.15	1.83±0.06	2.33±0.25
T2	1.7±0.1	1.53±0.12	1.4±0.1	1.93±0.06	1.67±0.06	1.93±0.06	0

T3	1.7±0.1	1.7±0.2	1.33±0.06	1.93±0.25	1.53±0.15	1.63±0.06	0
T4	1.7±0.1	1.27±0.15	1.83±0.06	1.57±0.06	1.60±0.1	1.80±0.1	1.97±0.06
C	1.7±0.1	1.63±0.21	1.77±0.06	2.13±0.12	2.20±0.2	0	0
	pH						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	4.02±0.06	3.93±0.06	4.39±0.05	5.85±0.05	5.68±0.09	6.48±0.05	6.99±0.11
T2	4.02±0.06	3.89±0.12	4.29±0.01	5.61±0.02	4.45±0.09	6.11±0.02	0
T3	4.02±0.06	3.86±0.03	5.28±0.02	5.39±0.05	4.96±0.04	5.98±0.01	0
T4	4.02±0.06	3.92±0.02	4.79±0.02	5.55±0.02	5.48±0.05	5.76±0.03	6.65±0.09
C	4.02±0.06	4.46±0.05	5.68±0.02	5.28±0.02	4.81±0.03	0	0

Effect on Total chlorophyll content

Total chlorophyll present in freshly harvested fruits was 3.5µg/ml (Table 5.3 and Figure 5.2). On 5th day of storage period, the chlorophyll content in T1 and T4 was 2.2µg/ml and 1.54µg/ml respectively which was significantly different than that of the control which showed 0.98µg/ml of chlorophyll. At 15th day the chlorophyll content decreased in all fruits T1 could retain chlorophyll contain up to 2.0µg/ml, on other hand same day the control showed only 1.17µg/ml. On the 20th day of storage the chlorophyll content in T1 and T4 was 3.39µg/ml and 1.44µg/ml respectively while fruits from control showed 0.77µg/ml. At the end of storage period the chlorophyll content in T1 and T4 was 0.81µg/ml and 0.73µg/ml. The fruits treated with T1 and T4 were effective for retaining the chlorophyll content of the fruit.

Effect on Ascorbic acid

The ascorbic acid content is decreased significantly during the ripening of postharvest mangoes. The ascorbic acid content observed in treated and untreated mangoes did not show significant difference till 15th day of storage, as represented in Table 5.3 and Figure 5.2. On 20th day of storage the ascorbic acid content recorded in T1 was significantly highest i.e. 10.53mg/100gm than any other treatment. On 25th day of storage the T3 and T4 showed 11.73mg/100gm and 11.53mg/100gm. At the day 30th there was significant difference in between the T1 and T4 where T1 showed 9.73 mg/100gm and T4 showed 15.43mg/100gm.

Effect on Total phenol content

The total phenols recorded at 0 day was 17.28mg/g. As represented in Table 5.3 and Figure 5.3, the total phenol found on 5th day of storage in T4 was 25.01mg/g, while in control it was significantly lower (9.21mg/g). On 10^{th} day of storage the total phenols seen in T4, T1 and control was 11.38mg/g, 15.05mg/g and 18.21mg/g respectively. At 15^{th} day T4 and T2 showed significantly higher level of total phenols i.e. 55.88mg/g and 61.71mg/g respectively. On 20^{th} day of storage period the total phenols recorded in T4 was significantly highest i.e. 39.18mg/g than any other treated fruits and that of control. At the end of storage, T4 showed 34.11mg/g of total phenols, while in T1 showed about 31.65mg/g of total phenols which was significantly lower than that of T4.

Effect on Antioxidant activity

The antioxidant activity of mangoes increased with the storage life in treated fruits. Freshly harvested mangoes were 71.86% (Table 5.4 and Figure 5.3). On 5^{th} day of storage the antioxidant activity noticed in T4 was 73.92% which was significantly higher than that of the control which showed about 17.10% of antioxidant activity. On 10^{th} day of storage the highest antioxidant activity was recorded in control i.e 95.26% and in fruits treated with T4 showed 86% of antioxidant activity. The antioxidant activity in fruits kept in control was found lowest i.e 78.57% on 15^{th} day, on other hand fruits treated with T4 and T3 showed 92.26% and 92.70% which was significantly different than that of the control. The fruits treated with T4 showed 89.12% of antioxidant activity and control showed 80.12% of antioxidant activity. At the end of storage period the antioxidant activity observed in T4 was 88.16% which was significantly higher than that of T1 which was 82.16%.

Table 5.3: Effect of physical elicitors and gum acacia on total chlorophyll, ascorbic acid and total phenol content of mango during their storage.

Treatments	Storage period (Days)						
	Total chlorophyll						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	3.54±0.16	2.22±0.12	2.08±0.09	3.39±1.63	1.24±0.35	1.35±0.22	0.82±0.02
T2	3.54±0.16	1.35±0.065	1.66±0.12	1.27±0.33	0.78±0.07	1.00±0.10	0
T3	3.54±0.16	1.25±0.06	1.18±0.04	0.80±0.17	0.87±0.07	1.04±0.16	0
T4	3.54±0.16	1.54±0.08	1.25±0.01	1.45±0.22	1.01±0.14	0.88±0.09	0.74±0.08
C	3.54±0.16	0.98±0.02	1.17±0.01	0.77±0.05	0.89±0.05	0	0
	Ascorbic acid						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	9.73±0.49	8.73±0.28	9.70±0.28	9.22±1.38	10.53±0.3	9.88±1.60	9.73±0.48
T2	9.73±0.49	9.45±1.32	8.92±0.45	9.23±1.30	9.02±0.13	10.80±3.19	0
T3	9.73±0.49	8.97±0.57	8.82±1.55	10.33±4.16	9.85±0.38	11.73±2.51	0
T4	9.73±0.49	9.12±0.64	10.37±2.83	12.42±0.80	9.23±0.1	11.53±2.21	15.43±0.31
C	9.73±0.49	8.53±0.54	10.40±1.64	11.08±0.46	9.40±0.14	0	0
	Total phenol content						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	17.29±0.44	11.05±0.38	15.05±0.21	22.69±0.6	21.19±1.04	32.49±2.15	31.65±0.57
T2	17.29±0.44	15.92±0.73	8.65±0.15	61.72±1.59	14.82±0.21	62.79±0.52	0
T3	17.29±0.44	13.49±0.1	8.85±0.06	21.49±1.13	34.09±1.48	22.65±0.15	0
T4	17.29±0.44	25.02±0.90	11.39±0.4	55.89±1.54	39.19±0.89	30.05±0.38	34.12±0.64
C	17.29±0.44	9.22±0.23	18.21±0.32	15.79±0.1	36.65±0.49	0	0

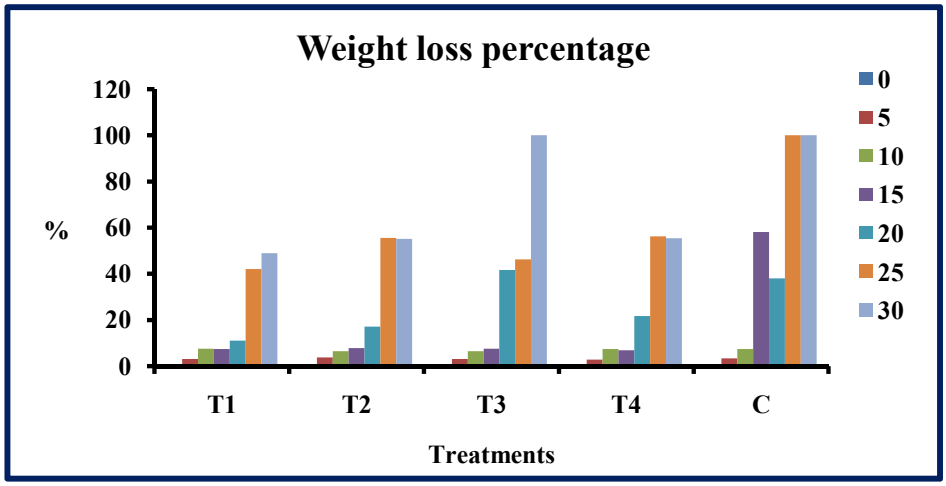
Table 5.4: Effect of different treatments on total chlorophyll, ascorbic acid and total phenol content of mango during their storage.

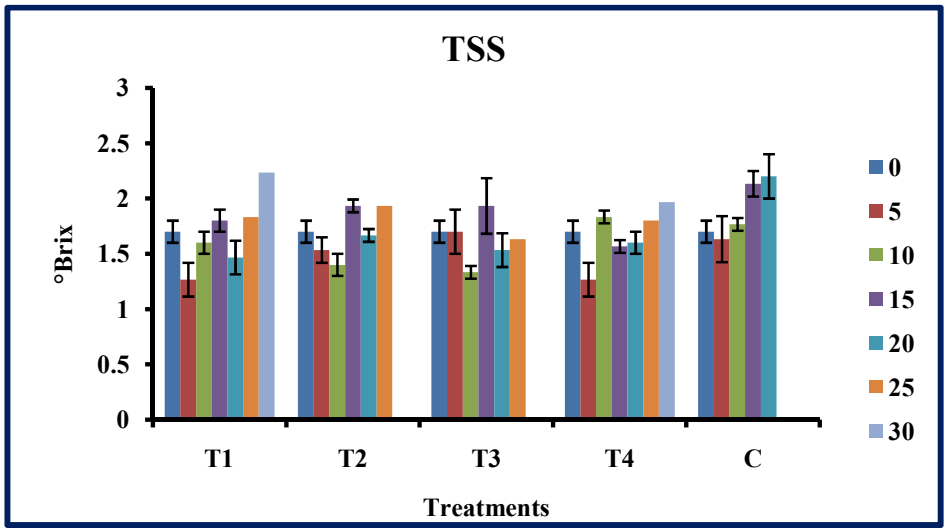
Treatments	Storage period (Days)						
	Antioxidant activity						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	71.86±4.42	47.73±4.67	82.21±3.09	92.18±1.06	86.08±0.57	80.63±2.47	82.17±0.92
T2	71.86±4.42	72.79±11.08	57.99±1.83	92.16±0.96	85.08±0.79	83.22±0.75	0
T3	71.86±4.42	55.47±10.26	53.42±0.52	92.70±0.31	88.68±2.02	83.50±0.0.47	0
T4	71.86±4.42	73.93±4.73	86.01±11.44	92.27±0.13	89.13±0.80	83.25±2.32	88.17±0.48
C	71.86±4.42	17.10±3.91	95.26±0.32	78.57±0.63	80.12±0.26	0	0

Publication of results:

A paper entitled, *"Gum acacia based edible coating combined with physical elicitors maintains nutritional quality and improves postharvest shelf-life of mango" authored by Sayali K. More and T. V. Ramana Rao has been* submitted for its presentation during 106th Session of Indian Science Congress to be held at Jalandhar, Punjab during Jan., 3 – 7, 2019.

Figure 5.1: Effect of physical elicitors and gum acacia on weight loss percentage, TSS and pH of mango during their storage.





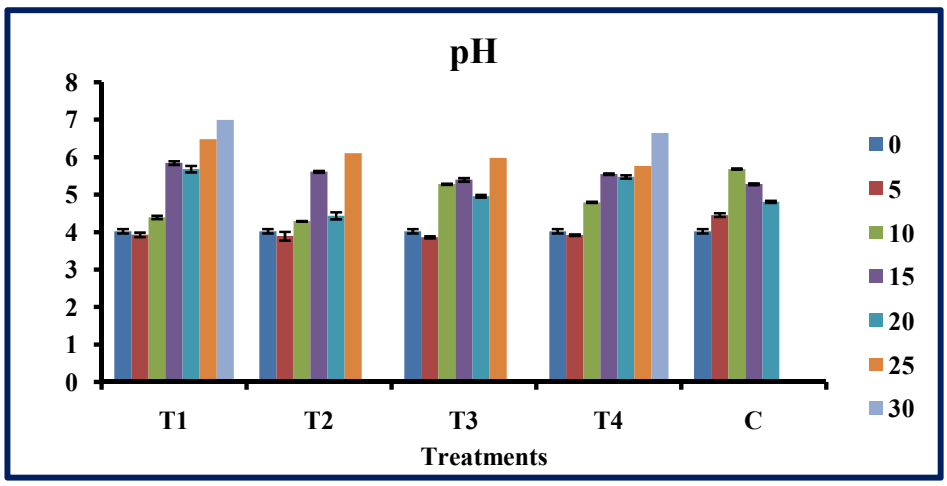
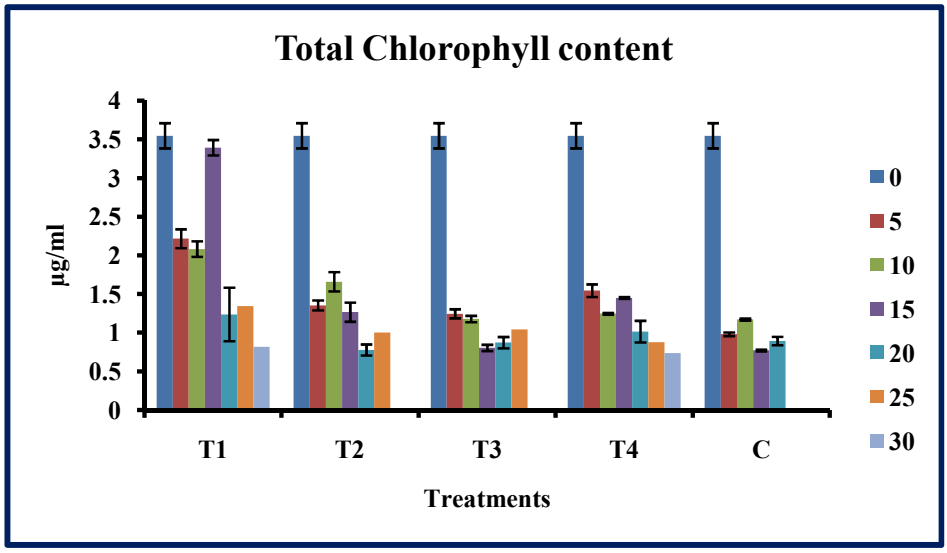


Figure 5.2: Effect of physical elicitors and gum acacia on total chlorophyll and ascorbic acid of mango during their storage.



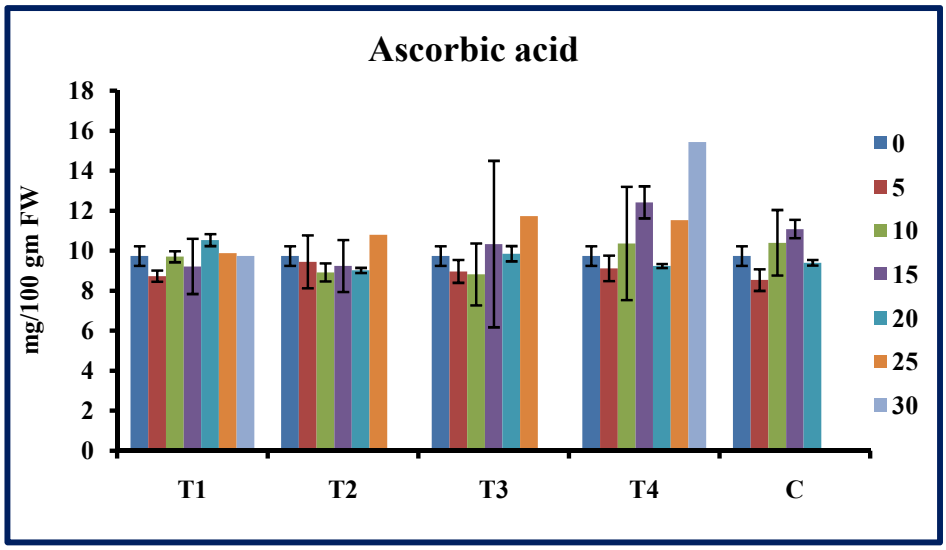
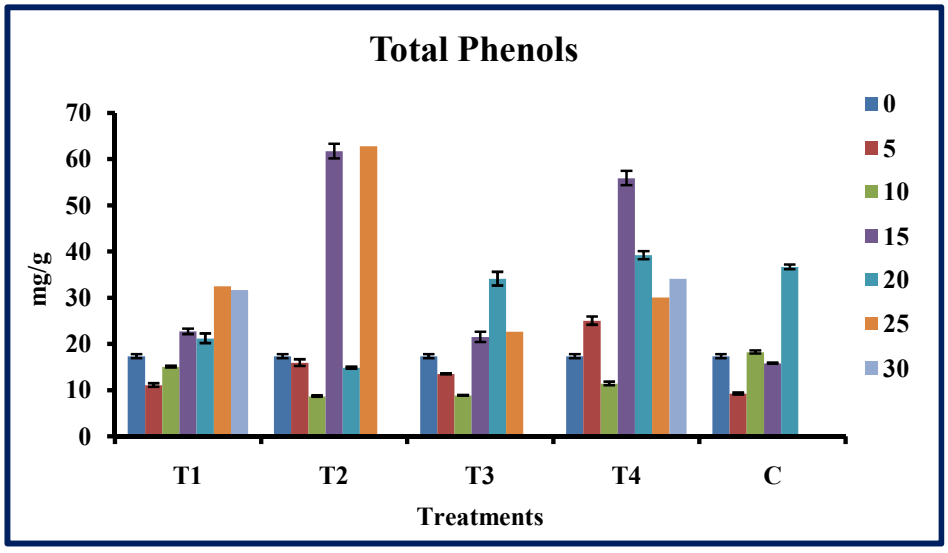


Figure 5.3: Effect of physical elicitors and gum acacia on total phenol content and antioxidant activity of mango during their storage.



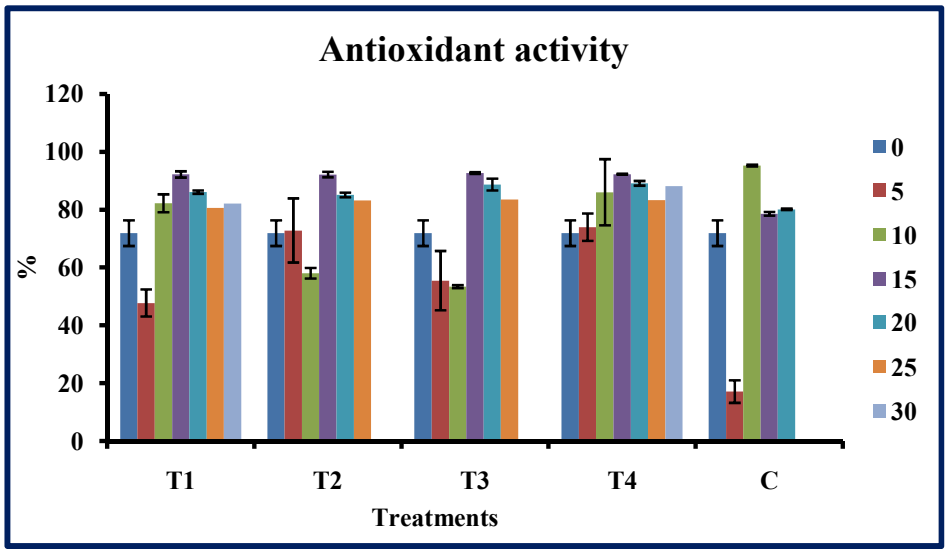


PLATE 5.1

A – Mango orchard, 'Saniya Kanade' village of Surat district, South Gujarat, India.

B – Mango kept for surface disinfection in 2% sodium hypochlorite solution.

C – Mango kept for air drying at room temperature after surface disinfection.

D – 5% Gum acacia solution

E – Mango fruit dipped in gum acacia coating solution

F – Laminarin solution

G – Photosensitization of mango fruit in chamber

H – Ozone water treatment of mango fruit

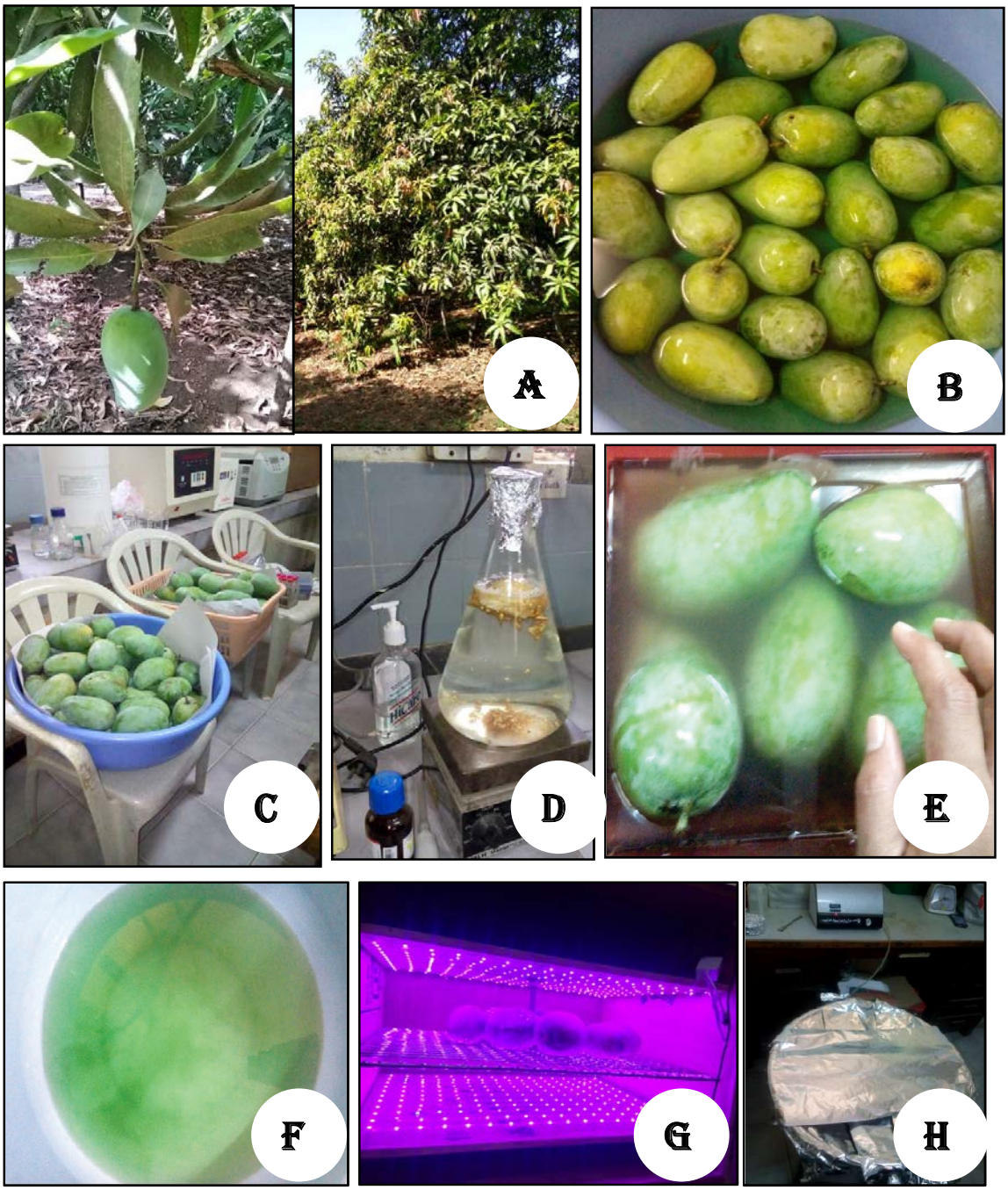


PLATE 5.1

PLATE 5.2

Effect of physical elicitors and gum acacia on visual quality of mango on 5th day of storage.

C - Control

T1 – Photosensitizer + 5% Gum acacia

T2 – 5% Gum acacia + 0.05% clove oil

T3 – T3 - 5% Gum acacia coating alone

T4 – Ozone water + 5% Gum acacia

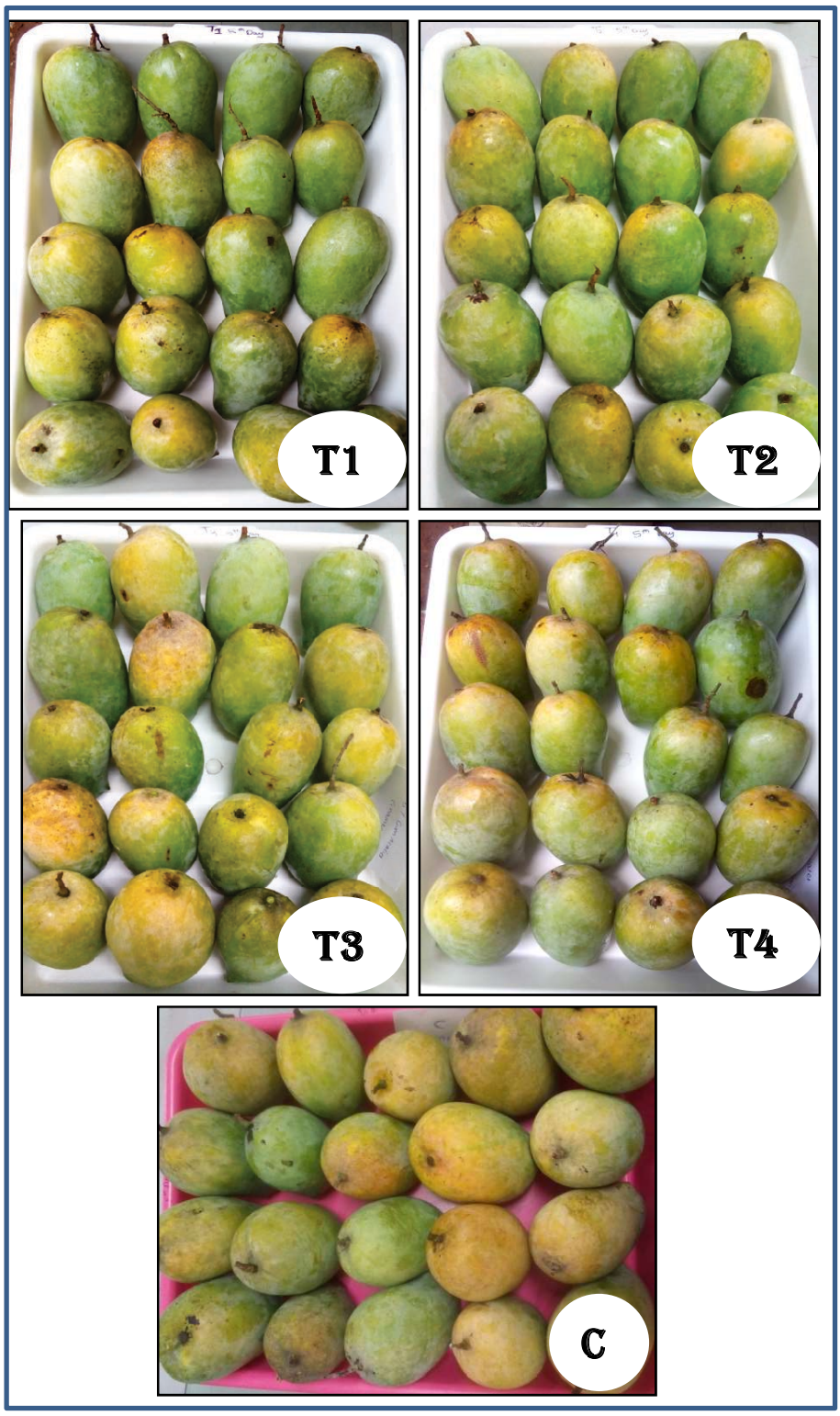


PLATE 5.2

PLATE 5.3

Effect of physical elicitors and gum acacia on visual quality of mango on 10th day of storage.

C - Control

T1 – Photosensitizer + 5% Gum acacia

T2 – 5% Gum acacia + 0.05% clove oil

T3 – T3 - 5% Gum acacia coating alone

T4 – Ozone water + 5% Gum acacia

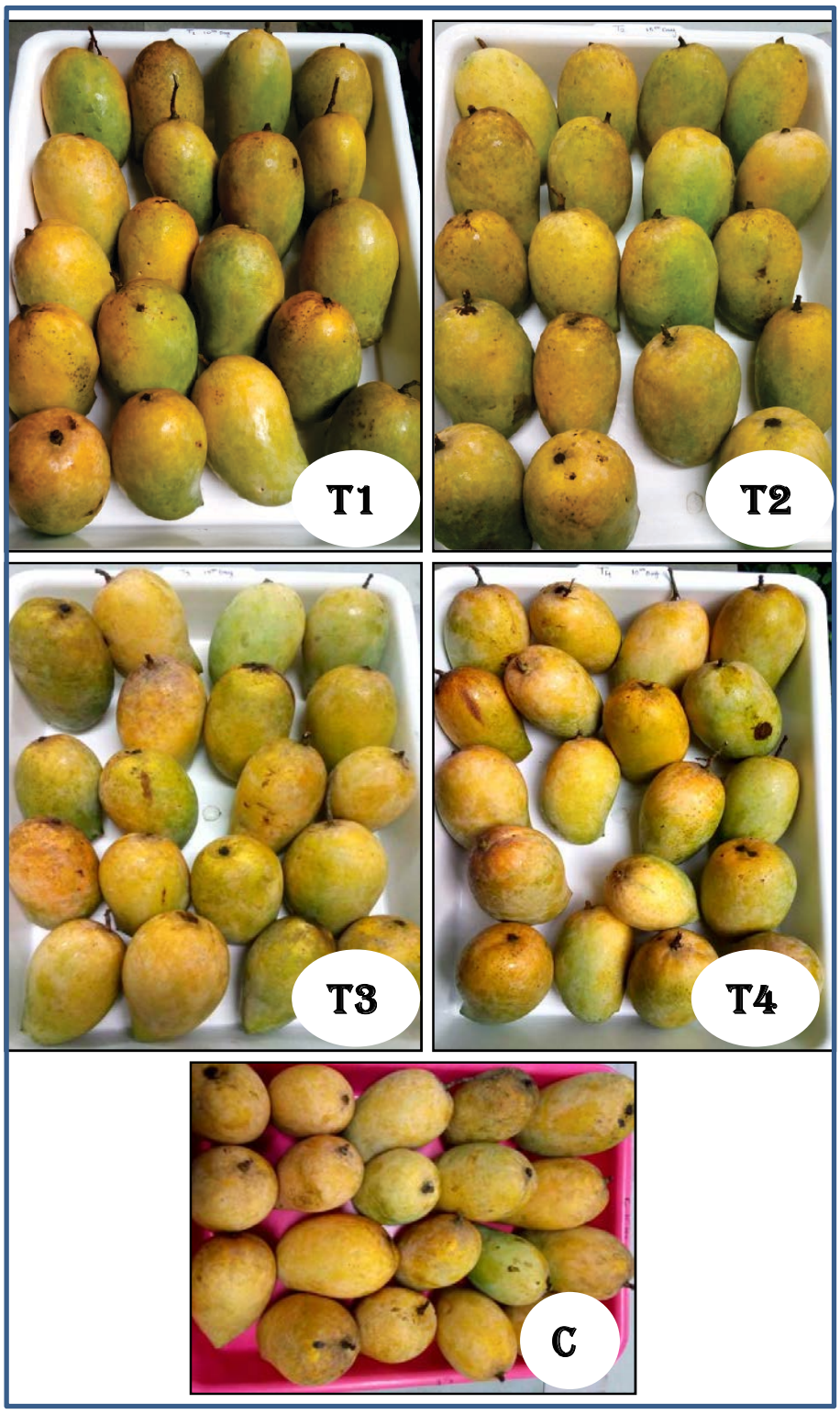


PLATE 5.3

PLATE 5.4

Effect of physical elicitors and gum acacia on visual quality of mango on 15th day of storage.

C - Control

T1 – Photosensitizer + 5% Gum acacia

T2 – 5% Gum acacia + 0.05% clove oil

T3 – T3 - 5% Gum acacia coating alone

T4 – Ozone water + 5% Gum acacia

PLATE 5.4

PLATE 5.5

Effect of physical elicitors and gum acacia on visual quality of mango on 20th day of storage.

C - Control

T1 – Photosensitizer + 5% Gum acacia

T2 – 5% Gum acacia + 0.05% clove oil

T3 – T3 - 5% Gum acacia coating alone

T4 – Ozone water + 5% Gum acacia

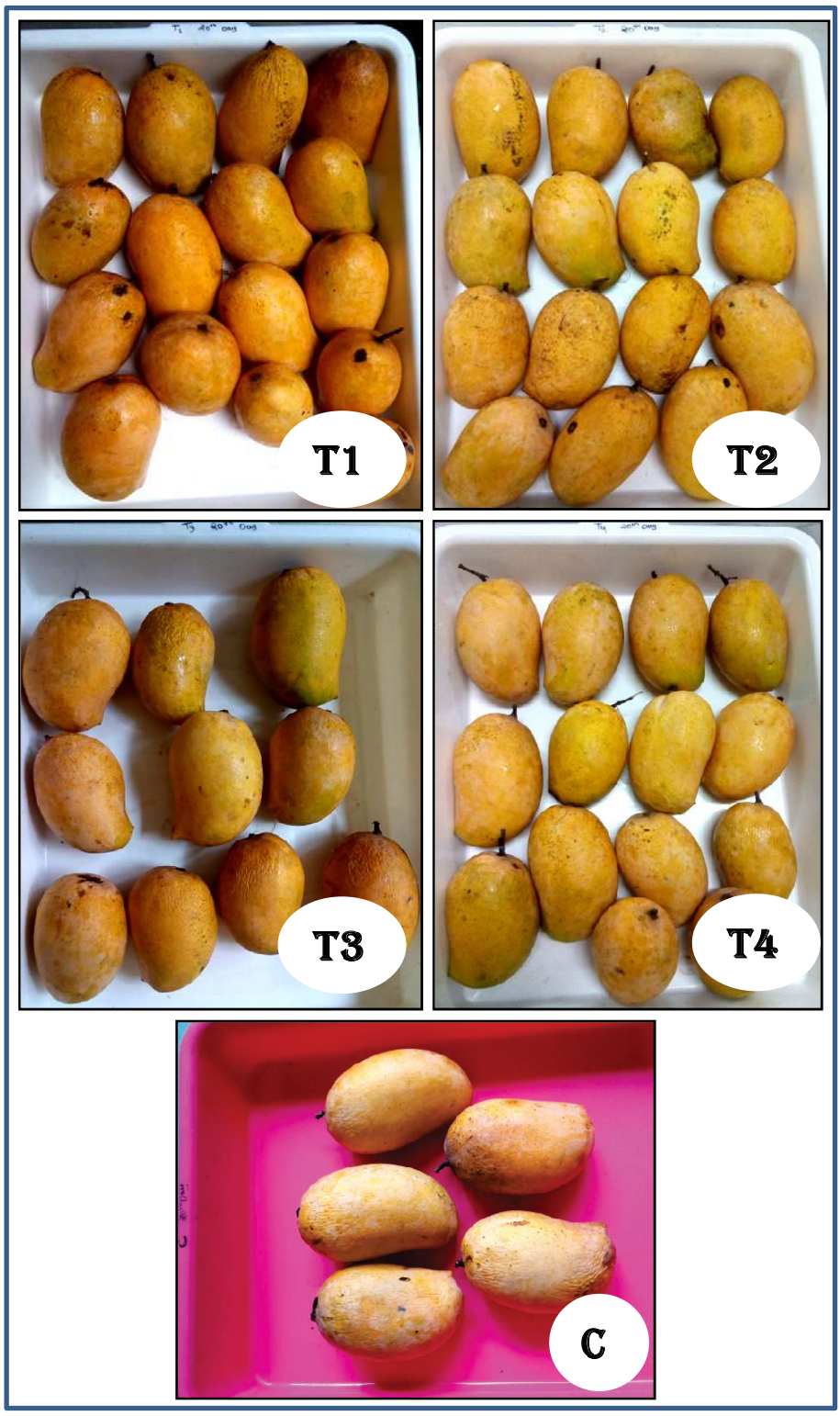


PLATE 5.5

Annexure IX

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. Title of the Project: ***Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf-life of some perishable horticulture produce***

2. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR:

Dr. ***T. V. Ramana Rao***

3. NAME AND ADDRESS OF THE INSTITUTION:

Department of Biosciences
Sardar Patel University
VALLABH VIDYANAGAR
Gujarat - 388120

4. UGC APPROVAL LETTER NO. AND DATE:

F. No. 43 – 117/2014 (SR)
dated 3 Dec. 2015

5. DATE OF IMPLEMENTATION: ***1st July 2015***

6. TENURE OF THE PROJECT: ***From 1st July 2015 to 30th June 2018***

7. TOTAL GRANT ALLOCATED: **Rs. 14, 60, 000/-**

8. TOTAL GRANT RECEIVED: **Rs. 9, 45, 000/-**

9. FINAL EXPENDITURE: **Rs. 9, 37, 323/-**

10. TITLE OF THE PROJECT: ***Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf-life of some perishable horticulture produce***

11. OBJECTIVES OF THE PROJECT:

1. Evaluation of antioxidant and antimicrobial nature of various natural extracts selected for the present study
2. Application of natural extracts on different short lived horticulrual products to improve postharvest quality and shelf life extension.
3. Elucidation of relationship between the biochemical and microstructural features of short-lived horticultural products selected for the present study so as to establish these features in improvement of nutritional quality and shelf life.
4. Microbiological and sensory analysis of coated as control samples during their storage period.

12. WHETHER OBJECTIVES WERE ACHIEVED (GIVE DETAILS):

The first two objectives of the project have been pursued successfully in totality and the significant results have been obtained. As the study has been extended with the physical elicitors like ozone water and photosensitization, the third and fourth objectives couldn't reach to significant accomplishment level.

13. ACHIEVEMENTS FROM THE PROJECT:

The edible coating compositions formulated during the present study for the short-lived commercial fruits can be scaled up and also these emulsions may be considered for other horticultural crops as well.

14. SUMMARY OF THE FINDINGS (IN 500 WORDS):

The production of fruits and vegetables significantly contribute to the economic growth of India. However, the deterioration of these horticultural produces due to factors like temperature, humidity, preservation method, handling at the time of storage and distribution, etc. effects their shelf-life and as a consequence it may lead to a great loss in terms of economy. Postharvest management of fruit and vegetable is necessary in order to have their proper utilization in appropriate manner like either freshly consumed or processed through selection of advanced preservation approaches. In the recent trend, consumers' are concern toward their health and therefore the demand for fruits and vegetable has been significantly increased. The application of naturally derived biopolymers (carbohydrates, lipids and proteins) and bioactive compounds with antimicrobial and antioxidant activity have gained lot of attention by food scientists and processors for improvement of postharvest quality and extension of shelf-life of perishable

fruits and vegetables. The present study aimed to develop eco-freindly safe preservation techniques by evaluation of plant derived compounds (polysaccharides and essential oil) and physical elicitors for quality improvement and shelf-life extension of selected perishable fruits viz. custard apple, guava, grapes, jamun and mango. Plant derived polysaccharides like guar gum, gum acacia, *Aloe vera* gel and essential oil (cinnamon and clove oil as antimicrobials) were explored either alone or in combination with physical elicitors like ozone water and photosensitizer. The result revealed from the present study that the application of guar gum (0.5%) enriched with clove oil (0.1%) extended the shelf-life and maintained the quality of custard apple during 8 days of storage period at 24°C. Guava fruit were found with improved quality and enhanced storage life up to 8 days compared to untreated guava fruit (4 days) after treatment with ozone water which is followed by 2% gum acacia supplemented with 0.1% cinnamon oil at 24°C. The beneficial role of pre-ozone treatment of jamun along with 0.5% and 1% *Aloe vera* gel was observed which extended the shelf-life of jamun up to 9 days of storage period at 10°C. The application of 25% *Aloe vera* gel was effectively enhanced the quality and storage life of grapes up to 24 days at 25°C. Photosensitization of mango fruit for 10 min and application of 5% gum acacia helped delayed the deterioration of mango and extended the shelf-life up to 20 days during storage at 25°C. Therefore, it can be concluded from the present study that the developed edible coatings for the selected fruit were effective and can be scale up and applicable to other horticultural crops.

15. CONTRIBUTION TO THE SOCIETY (GIVE DETAILS):

The results obtained from the work carried out under this investigation indicated that the plant derived polysaccharide based edible coating emulsions like guar gum, gum acacia, Aloe vera gel and essential oils (cinnamon and clove oil as antimicrobials) can be used either alone or in combination with physical elicitors like ozone water and photosensitizer for improvement of postharvest shelf life and retention of nutritional quality of perishable fruits like custard apple, guava, grapes, jamun and mango. As these are commercially important fruits, with these technologies, besides reducing postharvest losses, the availability of good quality fruits can be ensured for the trader, consumer and also for agro-processing industry, which in turn the grower may have the economical benefit. .

16. WHETHER ANY Ph.D. ENROLLED/PRODUCED OUT OF THE PROJECT:

- Nil -

17. NO. OF PUBLICATIONS OUT OF THE PROJECT (PLEASE ATTACH)

Research papers are not yet published from the work carried out under this project, but one paper entitled, *"Gum acacia based edible coating combined with physical elicitors maintains nutritional quality and improves postharvest shelf-life of mango" authored by Sayali K. More and T. V. Ramana Rao has been* submitted for its presentation during 106th Session of Indian Science Congress to be held at Jalandhar, Punjab during Jan., 3 – 7, 2019.

(PRINCIPAL INVESTIGATOR)

(REGISTRAR/PRINCIPAL)

(Seal)

Annexure - III

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

STATEMENT OF EXPENDITURE IN RESPECT OF MAJOR RESEARCH PROJECT

1. Name of Principal Investigator: **Dr. T. V. Ramana Rao**

2. Deptt. of Principal Investigator: **Department of Biosciences; Sardar Patel University**

3. UGC approval Letter No. and Date: **F. No. 43-117/2014 (SR) dated 3rd Dec. 2015**

4. Title of the Research Project: **Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf life of some perishable horticultural produce**

5. Effective date of starting the project:**01-07-2015 (vide UGC's letter dated 3rd Dec. 2015)**

6. a. Period of Expenditure: From: **April 2016 to June 2018**

b. Details of Expenditure _____

S. No.	Item Amount Approved (Rs.)	Expenditure Incurred (Rs.)
i. Books & Journals	**30,000/-**	**30,000/-**
ii. Equipment	**3,00,000/-**	**3,00,000/-**
iii. Contingency	**2,00,000/-**	**92,364/-**
iv. Field Work/Travel (Give details in the proforma at Annexure IV).	**30,000/-**	**7,829/-**
v. Hiring Services	**50,000/-**	**40,000/-**
vi. Chemicals & Glassware	**1,50,000/-**	**1,50,000/-**
vii. Overhead	**1,00,000/-**	**1,00,000/-**
viii. Any other items (Please specify)		

c . Staff

Date of Appointment: (i) 01-01-2016 - Mr. Kaushik A. Jodhani

(ii) 12-09-2016 - Ms. Komal Krupal Soni

(iii) 01-03-2017 - Ms. Shikha Tiwari

(iv) 14–02–2018 - Ms. Sayali K. More

S. No	Items	From	To	Amount Approved (Rs)	Expenditure incurred (Rs.)
1. Honorarium to PI (Retired Teachers) @ Rs. 18,000/- p.m.					
2. Project fellow: i) NET/GATE qualified-Rs. 16,000/- p.m. for initial 2 years and Rs. 18,000/- p.m. for the third year.					
ii) Non-GATE/Non-NET- Rs. 14,000/- p.m. for initial 2 years and Rs. 16,000/- p.m. for the third year.	**Non-GATE/Non-NET- Rs. 14,000/- p.m. for initial 2 years and Rs. 16,000/- p.m. for the third year.**	**Sept., 2016**	**June 2018**	**6,00,000/-**	**2,19140/-**

1. It is certified that the appointment(s) have been made in accordance with the terms and conditions laid down by the Commission.

2. If as a result of check or audit objection some irregularly is noticed at later date, action will be taken to refund, adjust or regularize the objected amounts.

3. Payment @ revised rates shall be made with arrears on the availability of additional funds.

4. It is certified that the grant of **Rs. 9,45,000/- (Rupees Nine Lakh Forty Five thousand only)** received from the University Grants Commission under the scheme of support for Major Research Project entitled "**Evaluation of biosafe products as an alternate**

strategy to improve the postharvest quality and shelf life of some perishable horticultural produce" vide UGC letter No. F. No. 43-117/2014 (SR) dated 3rd Dec., 2015. **Out of this, Rs. 9,37,323/- has been utilized** for the purpose for which it was sanctioned and in accordance with the terms and conditions laid down by the University Grants Commission.

SIGNATURE OF THE PRINCIPAL INVESTIGATOR	REGISTRAR	STATUTORY AUDITOR (Govt. Internal Auditor/ Chartered Accountant)
	(Seal)	(Seal)

Annexure - IV

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

STATEMENT OF EXPENDITURE INCURRED ON FIELD WORK

Name of the Principal Investigator: Dr. T. V. Ramana Rao

Name of the Place visited	Duration of the Visit		Mode of Journey	Expenditure Incurred (Rs.)
	From	To		
T. A. & D. A. of Subject Expert of Selection Committee Meeting held on 23rd August 2016	Anand Agri. Univ., Anand (to and fro)	Vallabh Vidyanagar	By Road	1080/-
Field trip for material collection from Savli, near Vadodara	Vallabh Vidyanagar (to and fro)	Savli	By Road	469/-
UGC Office, New Delhi for Mid-Term evaluation meeting	Vallabh Vidyanagar (to and fro)	New Delhi	By Rail	6,280/-

Certified that the above expenditure is in accordance with the UGC norms for Major Research Projects.

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

REGISTRAR

(Seal)

STATUTORY AUDITOR (Govt. Internal Auditor/ Chartered Accountant)

(Seal)

POST GRADUATE DEPARTMENT OF BIOSCIENCES
CENTRE OF ADVANCED STUDY IN BIORESOURCE TECHNOLOGY
SARDAR PATEL UNIVERSITY
Satellite Campus, Vadtal Road, Bakrol - 388 315, Anand, Gujarat, India

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Fax : +91-2692-231041 / 236475
E-mail : biosciencesoffice@spuvvn.edu

Annexure-VI

UGC File No. F. No. 43-117/2014(SR)
Dated: 3 Dec. 2015

DATE OF COMMENCEMENT 01 07 2015

TITLE OF THE PROJECT: Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf life of some perishable horticultural produce

1.	Name of the Principle Investigator	Prof. T.V.Ramana Rao				
2.	Name of the University/ College	Sardar Patel University				
3.	Name of the Research Personnel appointed	Kaushik A. Jodhani				
4.	Academic Qualification	S. No.	Qualifications	Year	Marks (CGPA)	Percentage
		1.	M.Sc. Botany	2013	7.05/10	70.50%
5.	Date of Joining	01/ 01/ 2016				
6.	Date of Birth of Research Personnel	06/ 08/ 1991				
7.	Amount of HRA, if drawn	——				
8.	Number of Candidate applied for the post	05 applied and 03 appeared for interview				

CERTIFICATE

This is to certify that all the rules and regulations of UGC Major Research Project outlined in the guidelines have been followed. Any lapses on the part of the University will liable to terminate of said UGC project.

Principle Investigator 12/2/16

Prof. T. V. Ramana Rao
Principal Investigator
UGC Major Research Project

Head of the Dept.

Head
Dept. of Biosciences
Sardar Patel University

I/c Registrar
Sardar Patel University
Vallabh Vidyanagar

SARDAR PATEL UNIVERSITY V.V. NAGAR

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Fax : +91-2692-231041 / 236475
E-mail : biosciencesoffice@spuvvn.edu

Annexure-VI

PROFORMA FOR SUPPLYING THE INFORMATION IN RESPECT OF THE STAFF APPOINTED UNDER THE SCHEME OF MAJOR RESEARCH PROJECT

UGC FILE NO. F.-43-117/2014(SR) **(HRP)** **YEAR OF: COMMENCEMENT** 01/07/2015

TITLE OF THE PROJECT: Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf life of some perishable horticultural produce

1.	Name Of the Principal Investigator	Prof. (Dr.) T. V. Ramana Rao				
2.	Name of the University/College	Sardar Patel University				
3.	Name of the Research Personnel appointed	Mrs. Komal Krupal Soni				
4.	Academic qualification	S. No.	Qualifications	Year	Marks	%age
		1.	M. Sc.	2012	5.70 CGPA	57%
		2.	M.Phill	-	-	-
		3.	Ph.D.	-	-	-
5.	Date of joining	12/09/2016				
6.	Date of Birth of Research Personnel	19/02/1990				
7.	Amount of HRA, if drawn	-				
8.	Number of Candidates applied for the post	10				

SARDAR PATEL UNIVERSITY V.V. NAGAR

CERTIFICATE

This is to certify that all the rules and regulations of UGC Major Research Project outlined in the guidelines have been followed. Any lapse on the part of the University wills liable to terminate of said UGC project.

28/9/16
Principal Investigator
Prof. T. V. Ramana Rao
Principal Investigator

28/9/16
Head of the Department
PROF. (DR.) T. V. RAMANA RAO
HEAD
DBD School of Biosciences
Sardar Patel University
Vallabh Vidyanagar - 388 120.
Dist. Anand. Gujarat

Registrar/Principal Registrar
Sardar Patel University
Vallabh Vidyanagar

Annexure - VI

ज्ञान-विज्ञान विमुक्तये

PROFORMA FOR SUPPLYING THE INFORMATION IN RESPECT OF THE STAFF APPOINTED UNDER THE SCHEME OF MAJOR RESEARCH PROJECT

UGC FILE NO. **F.43-117/2014(SR)** (HRP) YEAR OF COMMENCEMENT **01 /07/2015**

TITLE OF THE PROJECT: **Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf life of some perishable horticultural produce**

1.	Name of the Principle Investigator	**Dr. T. V. Ramana Rao**				
2.	Name of the University/Collage	**Sardar Patel University**				
3.	Name of the Research Personnel Appointed	**Shikha Tiwari** (Project Fellow)				
4.	Academic qualification	Sr. No.	Qualifications	Year	Marks	%age
		1.	**M. Sc.**	**2016**	**444/600**	**77.5**
		2.	M Phil	-	-	-
		3.	Ph D.	-	-	-
5.	Date of Joining	**01/03/2017**				
6.	Date of birth of Research Personnel	**28/12/1993**				
7.	Amount of HRA. If drawn	-				
8.	Number of Candidates applied for the post	**10**				

CERTIFICATE

This is to certify that all the rules and regulations of UGC Major Research Project outlined in the guidelines have been followed. Any lapse on the part of the University will liable to terminate of said UGC Project.

Principal Investigator

Head of Dept.

Head
Dept. of Bioscience
Sardar Patel University

RH Rajpara
Registrar
Sardar Patel University
Registrar
Vallabh Vidyanagar

SARDAR PATEL UNIVERSITY V.V. NAGAR

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Annexure - VI

PROFORMA FOR SUPPLYING THE INFORMATION IN RESPECT OF THE STAFF APPOINTED UNDER THE SCHEME OF MAJOR RESEARCH PROJECT

UGC FILE NO. **F.43-117/2014(SR)** (HRP) YEAR OF COMMENCEMENT **01 /07/2015**

TITLE OF THE PROJECT: **Evaluation of biosafe products as an alternate strategy to improve the postharvest quality and shelf life of some perishable horticultural produce**

1.	Name of the Principle Investigator	**Dr. T. V. Ramana Rao**				
2.	Name of the University/Collage	**Sardar Patel University**				
3.	Name of the Research Personnel Appointed	**Sayali K. More** (Project Fellow)				
4.	Academic qualification	Sr. No.	Qualifications	Year	Marks	%age
		1.	**M. Sc.**	**2011**	**1271/2000**	**63.55**
		2.	M Phil	-	-	-
		3.	Ph D.	-	-	-
5.	Date of Joining	**141/02/2018**				
6.	Date of birth of Research Personnel	**05/07/1988**				
7.	Amount of HRA. If drawn	-				
8.	Number of Candidates applied for the post	**02**				

CERTIFICATE

This is to certify that all the rules and regulations of UGC Major Research Project outlined in the guidelines have been followed. Any lapse on the part of the University will liable to terminate of said UGC Project.

Principal Investigator

Prof. T. V. Ramana Rao
Principal Investigator

Head of the Department

Head
Dept. of Bioscience
Sardar Patel University

O/c Registrar
Sardar Patel University
Vallabh Vidyanagar

Annexure – VII

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

MAJOR RESEARCH PROJECT COPY OF THE SPECIMEN OF HOUSE RENT FOR PROJECT FELLOW

Certified that Shri/Dr._____ is paying House Rent of Rs. _____ and is eligible to draw House Rent Allowances @_____ as per University Rules.

Registrar/Principal
(Signature with Seal)

Certified that Shri/Dr. _____ is not staying independently and therefore is eligible to draw House Rent @ of Rs. _____p.m. minimum admissible to a Lecturer as per University Rules.

Registrar/Principal
(Signature with Seal)

Certified that Shri/Dr. _____ has been provided accommodation in the Hostel. But he/she could not be provided with single seated flat type accommodation as recommended by the Commission, Hostel fee @ Rs._____ per month w.e.f. _____ is being charged from him/her.

Registrar/Principal
(Signature with Seal)

Date of Joining – 14-02-2018	Fellowship – 7500/-	HRA – 750/-
March 2018	Fellowship – 14000/-	HRA – 1400/-
April 2018	Fellowship – 14000/-	HRA – 1400/-
May 2018	Fellowship – 14000/-	HRA – 1400/-
June 2018	Fellowship – 14000/-	HRA – 1400/-