PROTOCOL DEVELOPMENT FOR FRESH-CUT FRUITS AND FRUIT MIX PREPARATION

by

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(2010-12-112)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

(Processing Technology)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF PROCESSING TECHNOLOGY

COLLEGE OF AGRICULTURE

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2012

DECLARATION

I, hereby declare that this thesis entitled **"Protocol development for fresh-cut fruits and fruit mix preparation"** is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

I bow my head before God Almighty for all the bountiful blessings he has showered on me at each and every moment without which this study would never have seen light.

Let me place on record of my profound feeling of gratitude and sincere thanks to my chair person of the advisory committee, ***Dr. Mini C.*** *Associate Professor and Head, Department of Processing Technology for her note worthy guidance, love, care creative suggestions and sustained interest. I am indebted to my major advisor for her constant encouragement, timely advice and friendly approach during the course of study as well as investigation and in the execution of this thesis.*

I would express my sincere gratitude to ***Dr. Manju R.V.*** *Associate Professor and Head, Department of Plant Physiology, for timely advice, care, friendly approach and guidance at all the stages of my research work.*

I am grateful to ***Dr. Anith K.N.*** *Associate Professor, Department of Plant Microbiology for his valuable suggestions and critical evaluation during the course of this work.*

I am thankful to ***Dr. Sreekala G.S.*** *Assistant Professor, Department of Processing Technology for her guidance and suggestions rendered to me in formulating the thesis.*

I accord my sincere thanks to ***Mr. S. Krishnan****, Junior Programmer of Department of Agricultural Extension for helping me in getting the data analysed.*

I wish to express my heartfelt thanks to ***Dean****, College of Agriculture, Vellayani for providing me all the necessary facilities from the university during the whole course of study.*

I am thankful to non-teaching staffs of the Department of Processing Technology- ***Archana chechi, Rameena, Babi chechi, Seena chechi*** *for their co-operation and support during the course of study.*

My heartfelt thanks to my dearest friend ***Kavitha****, who was always for me with loving support, care, confidence, moral support and so much more. Her care and constant encouragement has gone a long way in helping me to overcome the problems I had to face during the course of my work.*

I find special pleasure in expressing whole hearted thanks to seniors ***Adrika chechi , Shameena*** *for their valuable advice and guidance during course of my work.*

I wish to express my gratefulness to my classmate ***Sonia*** *for her great support and my beloved juniors, Thushara, Gajanan, for support and inspiration.*

From the depth of my heart I wish to thank my hostel friends for their affection, care, love and unforgettable help.

I owe a lifetime gratitude to my dearest ***Amma*** *(Mrs. Vijayalekshmi),* ***Achan (****Mohan P.K),* ***Chetan*** *(Praveen P K) and* ***chechi*** *(Sumitha Suresh) for their warm blessings, moral support and inspiring encouragement that was with me throughout this endeavour. The loving prayers of my family members have always helped me from beginning to end of my research work.*

Amith P. K.

Dedicated to My Ammi

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

LIST OF ABREVIATIONS

%	- per cent
^0B	- degree brix
CD	- Critical difference
cm	- Centimetre
CRD	- Completely Randomized Design
et al	- And others
Fig.	- Figure
g	- gram
i.e.	- That is
kg	- Kilogram
m	- metre
mg	- milligram
min	- minutes
ml	- millilitre
mm	- millimetre
^oC	- Degree Celcius
ppm	- parts per million
viz.,	- namely
lit	- litre
MAP	- modified atmospheric packaging
KMS	- potassium metabisulphite
Cm^2	- square centimeter
µl	- micro litre
cfu	- colony forming units
nm	- nano metre
TSS	- total soluble solids
PE	- polyethylene
PP	- polypropylene
KMnO4	- potassium permanganate
YI	- yellowness index
N	- Newton

Introduction

1. INTRODUCTION

The increasing popularity of minimally processed fruits and vegetables has been attributed to the health benefits associated with fresh produce, combined with the ongoing consumer trend towards eating out and consuming ready-to- eat foods. Minimally processed fruit and vegetable industry was initially developed to supply hotels, restaurants, catering services and other institutions. More recently, it was expanded to include food retailers for home consumption.

Minimally processed food (MPF) or fresh cut produce is defined as any fresh fruit, vegetable or any combination thereof, that has been physically altered from its original form, but remains in a fresh state. Unfortunately short shelf life is the major challenge faced; they undergo enzymatic browning, texture decay and microbial contamination, highly reducing their shelf life. The increasing demand of these fresh cut produce represents a challenge for researchers and processors to make them stable and safe. The increased time and distance between processing and consumption may contribute to higher risks of physical, chemical and microbial contaminants. The possible sources of contamination in these products involve the incoming raw fruits and vegetables, the plant workers and the processing environment. A characteristic feature in minimal processing is an integrated approach, where raw material handling, processing, packaging and distribution must be properly considered to make shelf life extension possible.

Physiology of minimal processed fruit or vegetable is essentially that of wounded tissue, which is detrimental to quality of fresh cut produce. When fruits and vegetables are peeled, chopped, cut or shredded, the release of plant cellular fluids provides a nutritive medium for microbial growth. High moisture content of fresh plant tissues, lack of lethal process to eliminate microbial pathogens and atmospheric temperature during preparation and handling further intensify the risks of hazards. Any processing technology for enhancing the convenience of consumer should definitely not affect the quality and safety of the produce.

With the increasing popularity of ready-to-eat, minimally processed, fresh or processed fruits and vegetables that are preserved only by relatively mild techniques, new ecological routes for microbial growth have emerged. To control microbial growth in these environments while keeping loss of quality at minimum, a hurdle technology approach appears to be the preservation technology of choice, that adequately ensures product safety and convenience. Many of the sophisticated technologies developed for enhanced shelf life may not be economically feasible in developing countries. By establishing an efficient and economic protocol for development of fresh cut fruits and fruit mix, consumers will be able to buy fresh fruits, which is in ready to use form. This type of convenient food will also increase the dietary consumption of fruits in present day busy life schedule. Hence a study on "Protocol development for fresh cut fruits & fruit mix preparation" was undertaken at the Department of processing Technology, College of Agriculture, Vellayani with the following objectives.

1. To standardize an efficient and economic protocol for development of fresh – cut fruits and fruit mix with extended shelf life
2. To study the acceptability of the standardized technology.

Review of Literature

2. REVIEW OF LITERATURE

‘‘Rich in cash/poor in time’’, there is a demand for ready to-eat products. The increasing demand for fresh fruits and vegetables and for convenience foods is causing an expansion of the market share for minimally processed products. In order to meet today's health conscious consumers’ demand for more fresh, natural, and convenient foods, concerted effort has been made to develop new methods for minimally processed fruit and vegetable products.

Research findings already reported by various workers on minimal processing of fruits and vegetables are reviewed here under.

2.1. Importance of fresh- cut fruits and vegetables

Consumer trends are changing, and high quality foods with fresh like attributes are demanded (Alzamora et al., 2005). Fresh-cut products are fruit or vegetables that have been trimmed and/or peeled and/or cut into 100per cent usable product that is bagged or prepackaged to offer consumers high nutrition, convenience, and flavour while still maintaining its freshness (IFPA, 2004).

Minimal processing technologies are modern techniques that provide sufficient shelf life to foods to allow their distribution, while also meeting the demands of the consumers for convenience and fresh-like quality. It can be applied at various stages of the food distribution chain, in storage, in processing and/or in packaging (Ohlsson,1994).

Consumer demand for tropical fresh-cut products is increasing rapidly in the world market, and fresh-cut pineapple is already found in many supermarkets and food service chains (Gonzalez-Aguilar et al., 2004; Marrero and Kader, 2006). Fresh-cut pineapple fruit is appreciated for its taste, flavor and juiciness. However, its shelf-life is limited by changes in color, texture, appearance, off-flavors and microbial growth which are affected by packaging conditions and storage temperature as well as cultivar and maturity stage (Fortuny and Belloso, 2003).

2.2. Physiological changes during fresh- cut product preparation

Fresh-cut fruits and vegetables are highly perishable due to damaged and exposed tissues and lack of protective skin. During the preparatory steps of minimal processing, the natural protection of fruit is generally removed and hence, they become highly susceptible to microbial spoilage (Watada and Qi, 1999).

Luna-Guzman and Barrett (2000) compared the effect of calcium chloride and calcium lactate dips in respiration of fresh-cut cantaloupe.

Minimally processed produce is known to be susceptible to the contamination and subsequent survival and/or growth of microorganisms resulting in both safety concerns and relatively short shelf lives (Parish et al., 2001).

Minimally processed fruit are one of the major growing segments in food retail markets. However, the greatest hurdle to commercial marketing is their limited shelf-life, which is due to excessive tissue softening and cut surface browning (Fortuny and Belloso, 2003).

The earliest physiological response to wounding is the enhanced production of ethylene and an enhanced respiration. Wounding plant tissues make them more susceptible to attack by pathogenic organisms and possibly more condusive to survival and growth of food poisoning microorganisms. Wounding can also directly influence flavor and aroma production (Morettie,et al.,2002)

Ethylene production is enhanced when plant tissue is injured by physical action of fresh- cut processing and ethylene accumulates in the packages of fresh- cut products leading to undesirable effect on quality during subsequent handling. Removal of peel results in a several fold increase in ethylene production compared to that of whole fruits and vegetables (Gorny et al.,2000).

The increase in respiration seen in wounded tissue is thought to be a consequence of elevated ethylene which stimulates respiration and enhance breakdown of starch. The respiration of minimally processed tissue ranges from a few to over 100per cent higher than that of intact produce. Minimal processing of vegetables induced stress and undesirable metabolic changes that reduced the product shelf life in relation to that of intact ones. The metabolic changes include increase in respiration and transpiration rates, pathological breakdown, synthesis of secondary metabolites and membrane lipid breakdown (Lana,2000).

Browning is also a major concern related to the extension of shelf-life of fresh-cut fruit, and strongly affects the consumer's purchase decision. Browning results from oxidation of phenolic compounds. Browning on the cut surface was most important cause of deterioration during storage and distribution (Artes et al., 2000). Total phenolics of fresh-cut apples during storage were found to be moderately correlated with browning index and not correlated with color degradation (Jeong et al.2008).

During mechanical operations, cut surfaces are damaged, releasing enzymes which spread through the tissue and come into contact with their substrates. The softening of fresh- cut fruit is mainly due to the enzymatic degradation of the cell wall, which is mainly composed of cellulose, hemicellulose and pectins. Enzymes such as pectin methylesterase (PME) and polygalacturonase (PG) generally play an important role in the fruit softening. PME demethylates pectin, resulting in the production of methanol and a pectin molecule with a lower degree of methylation. This allows depolymerization by PG, which breaks down α-1,4 glycosidic bonds, leading to cell wall degradation (Alandes et al., 2006).

2.3. Protocol for minimally processed foods

The vegetables or fruits intended for peeling and cutting must be easily washable, peelable, and their quality must be first-class. It is essential to use either a raw material free of contamination, or to clean/decontaminate the produce. The correct and proper storage of vegetables and careful trimming before processing are vital for the production of ready-to-use vegetables of good quality. The correct choice of variety is particularly important. Furthermore, climatic conditions, soil conditions, agricultural practices e.g., fertilization and harvesting conditions, can also significantly affect the behaviour of vegetables.

Sheela (2007) standardized the protocol for minimal processing of bread fruit and jack fruit. She had reported an enhanced shelf life by modified atmospheric packaging and low temperature storage. Varghese (2006) standardized the minimal processing techniques for selected vegetables. She had reported a shelf life of nine days for cowpea, okra, brinjal and ash gourd, ten days for pumpkin and elephant foot yam and 14 days for drumstick.

2.3.1. Sanitization

Efficacy of the sanitizers used to reduce microbial population is usually dependent upon the type of treatment, type and physiology of the target microorganisms, characteristics of produce and produce surfaces (cracks, crevices, texture, hydrophobic tendency), exposure tissue and concentration of sanitizer, pH, and temperature.

Whole fresh fruits before processing are washed with water containing chemical sanitizer agents such as chlorine, chlorine dioxide, tri sodium phosphate, hydrogen peroxide, organic acids and ozone to decontaminate the surface of the fruit; with chlorine being among the more effective chemical additives in reducing pathogenic or naturally occurring microorganisms (by the order of 10- to 100-fold) (Balla and Farkas 2006).

Several studies demonstrated that the application of chlorine dioxide, hydrogen peroxide and sodium hypochlorite can reduce populations of total aerobic bacteria, yeasts and moulds on the surface of tomato, sweet pepper, cucumber and strawberry (Alvaro et al., 2009; Kim et al., 2010).

Sodium hypochlorite (NaClO) is the most widely used sanitizer in the fresh-cut industry (Lee and Baek, 2008). Sodium hypochlorite fulfills many requirements as the ideal disinfectant and furthermore it has an excellent cleaning action. The effectiveness of sodium hypochlorite in the cleaning and disinfection processes depends on the concentration of available chlorine and the pH of the solution (Fukuzaki, 2006). Surface sterilization with sodium hypochlorite is effective in extending shelf life of fresh- cut tomato (Hong and Gross, 2001). Sodium hypochlorite was the active antimicrobial agent in the washing bath for processed cabbage, carrot, onion and Chinese cabbage (Dufkova, 2000)

Chlorine and other sanitizers are effective against microbial growth on inorganic surfaces and cutting equipments (Bacts and Tamplin, 2002).

Fantuzzi and Pushmann (2004) reported a reduced microbial population in minimally processed cabbage after sanitization for ten minutes with sodium hypochlorite at 200 mg/l.

2.3.2. Manufacturing practices

During the preparatory steps of minimal processing, the natural protection of fruit is generally removed and hence, they become highly susceptible to microbial spoilage. Manufacturing practices include techniques after sanitization including removal of inedible portions, cutting, slicing, shredding etc. The use of sharp knife, maintenance of stringent sanitary conditions etc substantially reduce damage to minimally processed tissues. Increased injury during preparation may directly affect visual quality and shelf life.

Cutting with very sharp knives resulted in clean cut surface, reduced number of cells damaged and appearance of white blush on carrot. Slicing and using sharp knife increases storage life of shredded and salad cut lettuce compared to chopping and using dull knife blade **(**Ahvenainen, 2000**).** Very sharp cutting tools would limit the number of injured cells while blunt cutting instrument could induce injury to cells.

2.3.3. Pretreatments

Surface treatments involving dipping fruit pieces into aqueous solutions containing antimicrobial agents, antioxidants, calcium salts or functional ingredients such as minerals and vitamins are widely practiced to improve quality of fresh- cut fruits.

Antimicrobials

Luna-Guzman and Barrett (2000) compared the effect of calcium chloride and calcium lactate dips in microbial load of fresh-cut cantaloupe.

Dipping treatments after peeling and/or cutting both reduce microbial loads and rinse of tissue fluids, and thus reduce the growth of microorganisms (Fortuny and Belloso, 2003**).** Immersing apple slices in sodium metabisulphite will reduce microbial population by 4 cfu/gram (Dipersio, etal; 2003).

Shredded cabbage treated with sodium metabisulphite at 1 per cent gave better shelf life (Roshita et al., 2005). Potassium metabisulphite or sodium benzoate in combination with ascorbic acid was found to retain visual quality, enhance shelf life and reduce microbial load during storage in fresh- cut pineapple (Sheela, 2007).

The search for methods to retard microbial growth is of great interest to all the sectors involved in production and preservation of and many different solutions have been proposed to delay the deterioration. Proliferation of microorganisms on the surface of fresh- cut fruits is currently retarded or inhibited by using low storage temperature, modified atmosphere packaging, and antimicrobial substances (Zavala et al., 2008.)

El-Mougy et al. (2008) demonstrated that a citric acid treatment significantly reduced linear growth and spore production of *Geotricum candidum, Penicillium digitatum, Penicillium italicum* on citrus.

Fan et al. (2009) identified sodium acid sulphate as an effective in inhibiting microbial growth in apple slices.

Anti- browning agents

Santerre et al. (1988) reported that application of citric acid can prevent browning of sliced apple and, thus, extended shelf life. A 2per cent (w/v) ascorbic acid 1 1per cent (w/v) calcium lactate post cutting dip resulted in limited reduction of cut surface browning in 'Carnival' peach slices. (Gorny et al., 2000)

Combination of several browning inhibitors were more effective (Gonzalez et al., 2000). Combination of 4-hexylresorcinol (0.001g/lit) + potassium sorbate (0.05g/lit) + acetyl cysteine (0.025g/lit) prevent browning and deterioration up to 14 days @ 10^0 C in apple.

Sliced Anjou pears had browning-free color for 30 days by dipping with 1.0per cent ascorbic acid and 1.0per cent calcium lactate, but texture was soft with juice leakage. The combination treatment of 0.01per cent 4-hexylresorcinol (4-HR), 0.5per cent ascorbic acid and 1.0per cent calcium lactate can provide 15 to 30 d shelf-life for Anjou, Bartlett, and Bosc pears when the pears are sliced at an average ripeness of 43, 49, and 38 Newton respectively, with 2 min dipping, partial vacuum packaging, and 2 to 5 °C storage (Dong et al., 2000).

Carboxylic acids such as oxalic acid and oxalacetic acid showed higher anti browning activity than citric acid on fresh- cut apples (Son et al., 2001).

Reducing agents such as citric acid, ascorbic acid, isoascorbic acid and sodium erythorbate (Sapers and Miller, 1998; Buta et al., 1999; Dong et al., 2000; Soliva-Fortuny,et al., 2002a), thiol containing amino acids such as N-acetylcysteine and glutathione (Oms-Oliu et al., 2007; Rojas-Grau et al., 2006), oxalic acid (Son et al., 2001) and 4-hexylresorcinol (Luo and Barbosa-Canovas, 1997) have been investigated to prevent browning.

Antibrowning agents can be divided into six groups including acidulants, reducing agents, chelating agents, complexing agents, enzyme inhibitors and enzyme treatments, based on inhibitory mechanisms. Dips of AA have long been applied in combination with organic acids and calcium salts to prevent enzymatic browning of fruit (Pizzocaro et al., 1993; Soliva-Fortuny et al., 2002b).

Romani (2004) revealed that combination of 0.2per cent ascorbic acid + 0.2per cent citric acid+ 0.2per cent calcium chloride is better for preventing browning during minimal processing.

Fresh- cut industry uses calcium ascorbates as anti browning agent to prevent discoloration (Karaibrachimoglu, 2004). Manganaris et al. (2007) compared the effect of calcium lactate, calcium chloride and calcium propionate dipping in peaches. Calcium increased in tissues with no dependence on the source used.

Lettuce phenolics were protected from oxidation by ascorbic acid and cysteine. Ascorbic acid and cysteine increased the total antioxidant activity of lettuce (Altunkaya and Gokmen, 2008)

Fan et al. (2009) identified sodium acid sulphate as an effective anti browning agent in apple slices.

Firming agents

A 2per cent (w/v) ascorbic acid 1 1per cent (w/v) calcium lactate post cutting dip resulted in limited reduction of tissue softening in ‘Carnival’ peach slices. (Gorny et al., 2000). Texture improvers – Calcium chloride is the most frequently used firming agent. Calcium lactate solution result in textural improvement similar to calcium chloride and had better flavour in cantaloupe melon (Dong et al., 2000). Luna-Guzman and Barrett (2000) compared the effect of calcium chloride and calcium lactate dips in fresh-cut cantaloupe firmness evaluation.

Calcium treatments can maintain or improve tissue firmness and crispness of fresh- cut fruit. Calcium chloride has been one of the most frequently used salts of calcium although it is reported to impart residual taste to the product. Thus, other calcium salts such as calcium lactate, calcium propionate or calcium ascorbate have been investigated as alternative sources of calcium (Dong et al., 2000, Gorny et. al., 2002., Alandes et al., 2006. and Quiles et al., 2007).

Calcium chloride has been widely used as preservative and firming agent in the fruits and vegetables industry for whole and fresh-cut commodities (Chardonnet, et al.,2003). Saftner et al., (2003) focused on the firming effect of calcium chloride treatment on fresh-cut honeydew and found calcium propionate, calcium chloride and calcium chelate treatments had doubled tissue calcium content and inhibited changes in honeydew chunks firmness.

A dip with calcium ascorbate reduced firmness loss of fresh- cut ‘Gala’ apples by approximately 13per cent after 3 weeks at 10 °C (Fan et al., 2005).

Forms of calcium used in the food industry are calcium lactate, calcium chloride, calcium phosphate, calcium propionate and calcium gluconate, which are used more when the objective is the preservation and/or the enhancement of the product firmness (Alzamora et al., 2005; Luna-Guzman and Barrett, 2000; Manganaris et al., 2007).

Calcium chloride ($CaCl_2$) has always been one of the most frequently used calcium salts when treating minimally processed fruit. The combination of a $CaCl_2$ treatment and packaging with a low O_2 concentration was more effective than the use of $CaCl_2$ alone to maintain firmness of fresh-cut ‘Piel de Sapo’ melons (Oms-Oliu et al., 2007), ‘Conference’ pears (Soliva-Fortuny et al., 2002b) and ‘Golden Delicious’ apples (Soliva-Fortuny et al., 2003) over several weeks of storage. By the end of storage of the apples and pears, microstructural observations showed that the original cellular structure of the fruit was not substantially altered. The drawback to this calcium salt is that it contributes to a bitter taste in the product (Luna-Guzmán and Barrett, 2000; Saftner et al., 2003; Lamikanra and Watson, 2003 and [Hernandez-Munoz et al., 2006).

Treating fresh- cut ‘Golden Delicious’ apples with calcium ascorbate and electrolysed water reduced softening for 21 d at 4 °C (Wang et al., 2007).

Quality improvers

Color, ethylene production and respiration of broccoli (*Brassica oleracea* L. var. italica) dipped in hot water (45 °C, 10 minutes; 47 °C, 7.5 minutes; and 20 °C, 10 minutes as control) were measured (Tian et al., 1997). Following HWT of 47 °C for 7.5 minutes, respiration, starch, sucrose, and soluble protein content of florets and stems decreased dramatically during the first 10 to 24 hours after harvest. At the same time, fructose contents in florets and stems increased. Glucose increased in the florets but decreased within 24 hours in stems. Thereafter, glucose and fructose in florets and stems decreased. Sucrose content in florets and stems increased dramatically within a short period of treatment (<10 hours) and then declined.

Treatment with 0.1M citric acid markedly extended the shelf life, inhibited surface coloration and disease development, and reduced the loss in eating quality associated with the contents of ascorbic acid and total soluble solid, titratable acidity and ascorbic acid. It is suggested that application of citric acid better maintained quality and extended shelf life of fresh-cut Chinese Water Chestnut (Jiang et al, 2004).

Oms-oliu et al. (2006) reviewed recent advances for the maintenance of fresh-cut quality with respect to the use of chemical compounds, including plant natural antimicrobials and antioxidants, as well as calcium salts for maintaining texture. It focuses especially on the use of natural preservatives, which are of increasing interest because of toxicity and/or allergenicity of some traditional food preservatives. The difficulties in the application of these substances on fresh- cut fruit without adversely affecting sensory characteristics of the product are reviewed. Edible coatings are presented as an excellent way to carry additives since they are shown to maintain high concentrations of preservatives on the food surfaces, reducing the impact of such chemicals on overall consumer acceptability of fresh- cut fruit.

The influence of dipping in ascorbic acid, citric acid and calcium chloride (AA + CA+ CaCl2) solution and storage time on color, bioactive compounds content and antioxidant activity of fresh-cut mango 'Kent' stored at 5 ◦C was evaluated. The treated mangoes showed better color retention during storage than control mangoes. The dipping treatments with AA+ CA+ CaCl2 significantly increased the vitamin C values compared with untreated mango cubes (Robles-Sanchez et al,2009)

2.4. Packaging and storage

Fresh-cut kiwifruit slices had a shelf-life of 9–12 days if treated with 1per cent $CaCl_2$ or 2per cent Calcium lactate, and stored at 0-2°C and >90per cent relative humidity in an C_2H_4 free atmosphere of 2 to 4 k Pa O_2 and/or 5to10 kPa CO_2 (Agar et al., 1999).

Kale and Kadavu (2003) revealed that packaging with micro-perforation lead to retention of product quality in respect of fresh weight, firmness, sugar/acid ratio and thus a reduction of deterioration and prolonged shelf life.

Polypropylene could extend the shelf life of minimally processed shredded cabbage almost up to three weeks with minimum colour change, reduction in weight loss and deterioration in sensory properties. (Roshita et al. 2005). They also revealed that samples in vacuum packaging showed no significant difference compared with those in non- vacuum packaging in almost all the parameters tested for all the packaging films used.

Removal of ethylene from the storage environment of minimally processed fruits and vegetables can retard tissue softening (Abe and Watada, 1991). Packaging in polyethylene cover along with a sachet of potassium metabisulphite extended shelf life of fresh- cut cowpea and coleus (Sheela, 2007).

Fresh- cut fruits and vegetables generally are packaged in film bags or containers , over wrapped with film, which create a modified atmosphere within the modified atmospheric package (MAP). Gorny (2001) reported that MAP can extend shelf life of many intact and fresh- cut horticultural products.

Aguayo et al. (2010) reported a shelf life of 21-28 days for fresh- cut apple slices dipped in 6 or 12per cent calcium ascorbate and stored in MA packaging.

The effects of various modified environments on retention of quality attributes of Chinese organic red raspberry (*Rubus idaeus* L.) and sea-buckthorn (*Hippophae rhamnoides* L.) fruit from northeast China were assessed (Barth et al., 2011). Improved color retention was shown in MAP-stored raspberry fruit. Better retention of cohesiveness and springiness were observed in MAP-treated raspberry fruit with slightly better results noted in lower oxygen transmission rate. No differences noted for sea-buckthorn fruit texture. MAP resulted in improved moisture retention and lower TSS vs. control in both fruit. Overall MAP improved quality retention of Chinese, organic raspberry and sea-buckthorn fruit.

2.5. Acceptability studies by sensory analysis

It is important that knowledge about sensory characteristics is related to consumer likes or dislikes about the product. Sensory analysis is the identification, scientific measurement, analysis and interpretation of the properties (attributes) of a product as they are perceived through the five senses of sight, smell, taste, touch and hearing (Carpenter et al. 2002). Organoleptic evaluation for judging consumer acceptability is essential for any food product (Bini, 2003).

Moskowitz (1981) introduced a new approach for evaluating the relative importance of sensory characteristics to acceptance, using quadratic relations. The analysis illustrates that the relative importance of any specific characteristic cannot be defined as a single number, but depends upon the level of that characteristic as perceived by the consumer, and upon the other sensory factors of the product.

Luna-Guzman and Barrett (2000) compared the effect of calcium chloride and calcium lactate dips in sensorial evaluation of fresh-cut cantaloupe.

When sensory analysis was conducted participants could not distinguish between pear slices treated with 2per cent (w/v) ascorbic acid solution and stored overnight at 0 °C and freshly prepared control pear slices. After 10 days storage in air at 0 °C, 82per cent of participants judged treated pear slices to be acceptable in appearance and 70per cent judged flavor to be acceptable (Gorny et al.2002).

Treatment with 200 mg/l sodium hypochlorite or with 250 mg/l peroxy acetic acid changed the sensory quality of cooked leek significantly, when compared with water washing (Vandekinderen et al, 2008)

An integrated sensory approach, involving instrumental/sensory correlations, has been published by Varela et al. (2007) in order to evaluate the use of different calcium salts in fresh-cut apples. Their results showed that a dipping of 1per cent $CaCl_2$ for 3 min for fresh-cut 'Fuji' apples maintained the overall acceptability of the samples for at least 8 d of storage.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Protocol development for fresh- cut fruits & fruit mix preparation" was undertaken at the Department of processing Technology, College of Agriculture, Vellayani, during the period of 2010-2012, with the objective to standardize an efficient and economic protocol for development of fresh-cut fruits and fruit mix with extended shelf life and to study the acceptability of the standardized technology.

Protocol for fresh- cut fruit preparation includes surface sanitization, pre-treatment of cut pieces, packaging and storage. The investigation was carried out as four different continuous experiments (Steps)

1. Evaluation of different sanitizing agents
2. Evaluation of different pre-storage treatments
3. Development of packaging system
4. Quality parameters and acceptability of standardized protocol

Mango, papaya, pineapple and pomegranate were used individually and in combination. Good quality, fresh, optimum mature fruits, free from visual defects and relatively uniform size, weight and colour were collected from the local market and used for the study.

3. 1. EVALUATION OF DIFFERENT SANITIZING AGENTS

Fruits were washed in tap water, and treated with the following sanitizing solutions for surface de-contamination of whole fruits. One kilogram each of whole fruit was immersed in following different sanitizing solutions prepared in distilled water for 15 minutes in such a way that the whole produce gets immersed in solution (Plate 1.).

Plate 1.Surface Sanitization of whole fruits

Plate 2. Pre treatment of fruit pieces

T_1 - 40^oC water

T_2 - 30ppm sodium hypochlorite

T_3 - 60ppm sodium hypochlorite

T_4 - 90ppm sodium hypochlorite

T_5 - 120ppm sodium hypochlorite

T_6 - Control (Washing with Tap water)

Solutions were drained after treatment; $1cm^2$ area of skin/ peel of the sanitized fruits were cut and separated from fruits using a sharp sterilized blade. In order to avoid cross-contamination during sample preparation, knives, cutting boards and other equipments coming in contact with fruits were sanitized by immersing in 1000 ppm sodium hypochlorite solution for 10 minutes. Disposable gloves were worn during the treatment of fruits and preparation of peel pieces.

The treated peel pieces were evaluated for microbial count, as detailed below and based on the efficiency in controlling the microorganisms; the best sanitizing agent was selected for each fruit.

3.1.1. Enumeration of total microbial load

The quantitative assay of the micro fauna in pre and post treated samples was carried out by serial dilution spread plate technique. Nutrient agar and Sabourd Dextrose agar medium were used for the enumeration of bacterial and fungal population of the peel pieces respectively.

The cut skin piece of one cm^2 area was suspended in 100 ml sterile distilled water and shaken thoroughly for 2 minutes. One ml of the supernatant was accurately pipetted out into eppendroff tube containing 900 µl of sterile distilled water to get 10^{-3} dilution. This procedure was repeated to get 10^{-6} dilution. 100µl each of 10^{-2}, 10^{-4} & 10^{-6} was used for enumeration of total bacterial and fungal count. Bacterial count was noted for three days continuously from the next day of inoculation whereas fungal count was taken from three days after inoculation. Number of micro organisms (bacteria and fungi) per cm^2 of pre and post treated sample was calculated as per the following formula

$$\text{No. of colony forming units (CFU) per gram of the sample} = \frac{\text{Total number of colony formed x dilution factor}}{\text{Aliquote plated}}$$

Analysis of Co- variance was conducted for assessing the post treatment effect using pre- treatment as the covariate and the most effective sanitizing solution was determined for each fruit.

3. 2. EVALUATION OF DIFFERENT PRE-STORAGE TREATMENTS

Chemical treatments are used in fresh- cut fruits for controlling decay, reducing browning and retaining firmness. The comparative efficiency of the different solutions in extending shelf life of fresh- cut fruits was studied.

The individual whole fruit was surface sanitized using the best method selected for each fruit under the first step of experiment (3.1.). Sanitized fruits were peeled; inedible portions were removed and cut into ≈ 2 cm cube pieces. Hundred grams of fresh-cut fruits and freshly separated pomegranate arils were completely immersed in following different solutions for 10 minutes (Plate 2.).

T_1 → 0.1% KMS and 0.1% ascorbic acid

T_2 → 0.1% KMS and 0.1% citric acid

T_3 → 0.1% Sodium benzoate and 0.1% ascorbic acid

T_4 → 0.1% Sodium benzoate and 0.1% citric acid

T_5 → Calcium Chloride (1%)

T_6 → Calcium Ascorbate (1%)

T_7 → Sodium Acid Sulphate (3%)

T_8 → Control (Without any Treatment)

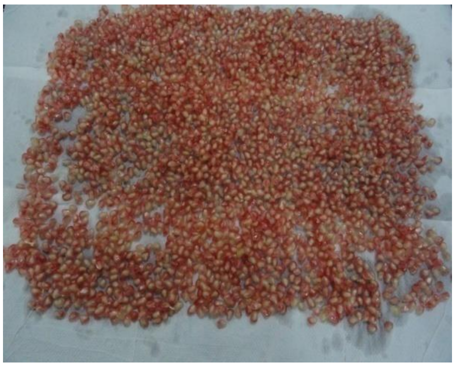
Plate 3. Air drying of treated fruit pieces

Mango

Papaya

Pineapple

Pomegranate



After 10 minutes of soaking, the treated fresh- cut fruit pieces and pomegranate arils were taken out from solution, drained and allowed to air dry (Plate 3.). The treated materials were weighed, kept in containers made of aluminum foil, covered with their own lid and stored under ambient conditions.

The following physical, physiological and chemical quality parameters of the treated fruit samples were recorded at the time of storage and for a period of five days.

3.2.1. Physical Parameters

The physical parameters like colour, texture, appearance, flavor and taste were examined by conducting a sensory evaluation performed by a 10 member semi trained panel. The panel were asked to evaluate these sensory attributes along with juiciness and total freshness by organoleptic scoring using a nine point hedonic scale (Appendix.I).

Like extremely - 9
Like very much - 8
Like moderately - 7
Like slightly - 6
Neither like nor dislike - 5
Dislike slightly - 4
Dislike moderately - 3
Dislike very much - 2
Dislike extremely - 1

The scores given by the 10 judges were statistically analysed using Kendalls'(W) test and mean ranks were obtained for the quality parameters evaluated.

3.2.2. Physiological parameters

Physiological parameters were recorded continuously for a period of five days and the observation were averaged over the storage period of five days.

3.2.2. 1. Physiological loss in weight (PLW)

During the storage period of five days, per cent weight loss (Physiological loss in weight) was determined on initial weight basis by weighing the fruit samples on the day of observation, using a laboratory level weighing balance having 0.01g accuracy, using the following formula and expressed as percentage.

$$PLW = \frac{\text{Initial weight- Final weight}}{\text{Initial weight}} \times 100$$

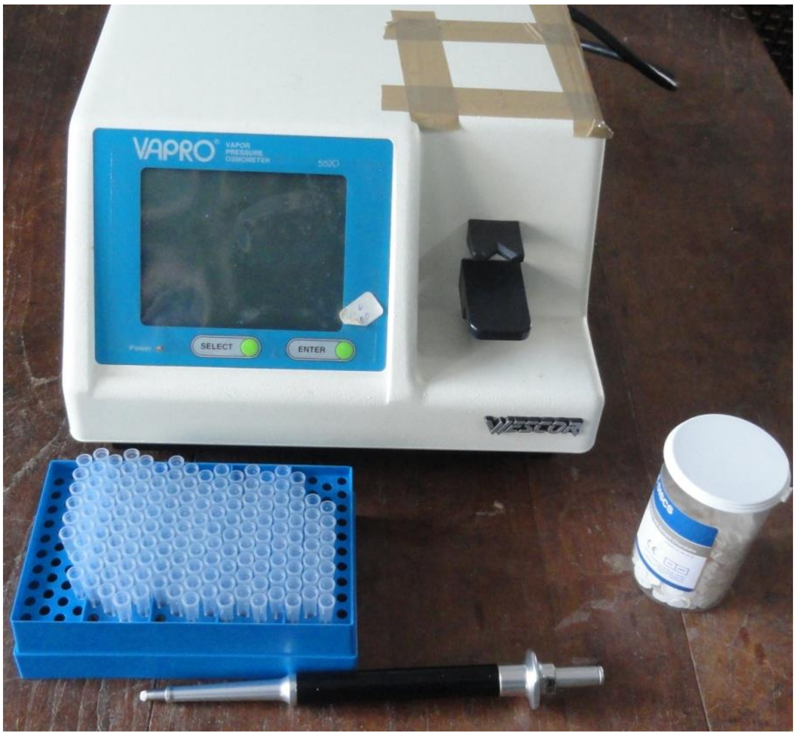
3.2.2. 2. Osmotic Potential

The fruit pieces were squeezed out to extract juice and 1 ml of fruit juice was taken in a micropipette and osmolality was read using Vapro- Vapour Pressure osmometer (5520) (Plate 4.).

3.2.2. 3. Percent leakage

Uniform sized fruit pieces were made into thin slices, immersed in 20 ml distilled water for 3 hours and absorbance was read in a UV spectrophotometer at 273 nm. The immersed slices were heated in water bath at 100^0C for 20 minutes, filtered; filtrate is made upto 20 ml, the absorbance was read again in UV spectrophotometer at 273 nm. Percent leakage was calculated using the following formula and expressed as percentage.

Plate 4. Vapro- Vapour Pressure Osmometer



$$\text{Percent leakage} = \frac{\text{Initial absorbance value}}{\text{Final absorbance value}} \times 100$$

3.2.3. Chemical parameters

Following chemical parameters were recorded continuously for a period of five days and averaged over the storage period.

3.2.3. 1. Acidity

Titratable acidity of treated fruits was estimated as per the procedure described by Ranganna (1991) and expressed as per cent anhydrous citric acid.

3.2.3. 2. Total Soluble Solids

Total Soluble Solids (TSS) was recorded directly using Erma Hand refractometer (range 0-32^0 brix) and expressed in degree brix (^{o}B)

3.2.3. 3. Starch

Starch content of treated fruits was determined as per the procedure described by Saini et al (2001) and expressed as per cent.

3.2.3. 4. Vitamin C

Vitamin C content of the treated fruits was estimated quantitatively by 2,6-dichloro phenol indophenol (DIP) dye method (Saini et al., 2001) and expressed as mg/100g of treated fruits sample.

3.2.3. 5. Carotenoids

Carotenoids were estimated as per the procedure of Saini et al. (2001) and expressed as mg/100g of treated fruit.

3.2.3. 6. Total Phenol

Total phenol of the treated fruit samples was estimated by standard method (Sadasivam and Manikam, 1992) and expressed as mg/100g of treated fruit sample.

As none of the treatments showed superior performance for all the quality parameters evaluated, different chemical and physiological parameters were given comparative ranks from 6-1 based on the importance and weighted average rank (W.A.R.) was calculated for different treatments.

$$\text{W. A. R.} = \frac{[(6\times \text{TSS}) + (-5\times \text{acidity}) + (4\times \text{Vitamin C}) + (3\times \text{carotenoid}) + (-2\times \text{phenol}) + (1\times \text{starch})]}{(6+5+4+3+2+1)}$$

Based on the WAR, the top four pre-treatments were selected for further microbial analysis.

3.2.4. Enumeration of total microbial load

The top four pre-treatments, selected for each fruit, based on the weighted average rank, were used for microbial analysis. Microbial count of one gram treated fruit samples was calculated once in two days for five days, as described in 3.1.2.

Based on the efficiency in controlling the microbial populations, the best pre-storage treatment solution was determined for each fruit.

3. 3. DEVELOPMENT OF PACKAGING SYSTEM

This experiment was formulated with the objective of evolving an efficient packaging material for fresh- cut fruits.

The best sanitizing and pre-storage treatment selected for each fruit in the first and second part of the experiments respectively were adopted in this part of the study. After surface sanitization and pre-storage treatment, fresh-cut fruits were prepared as in part 2 of the experiment, 100 g. weighed and packed in following different packaging materials (Plate 5.). In the case of fruit mix, 25 g of each fruit was given the respective sanitization and pre- treatment selected during the previous experiments and mixed together to form the fruit mix

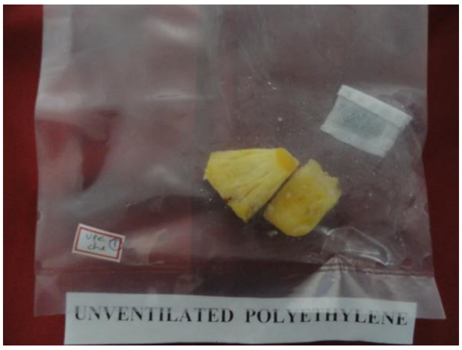
T_1- unventilated PE cover(150 gauge)
T_2- unventilated PP cover(100 gauge)
T_3-micro ventilated PE cover(150 gauge)
T_4- micro ventilated PP cover(100 gauge)
T_5- Aluminium tray with cling film
T_6- polystyrene tray with cling film
T_7- T_1+ $KMnO_4$ sachet
T_8- T_2+ $KMnO_4$ sachet
T_9- T_3+ $KMnO_4$ sachet
T_{10}- T_4+ $KMnO_4$ sachet
T_{11}- T_5+ $KMnO_4$ sachet
T_{12}- T_6+ $KMnO_4$ sachet
T_{13}- control (open storage in paper plate)

In treatments from T_1 to T_4 and treatments from T_7 to T_{10}, fresh- cut fruits were packed in plastic (PE/PP) covers of 0.18 m^2 area. In T_3, T_4 T_9 and T_{10}, covers of similar size were perforated by making total of six pores on both sides of the packages.

Plate 5. Packaging materials used for the study

Polyethylene

Polypropylene



Aluminium tray with cling film

Polystyrene tray with cling film

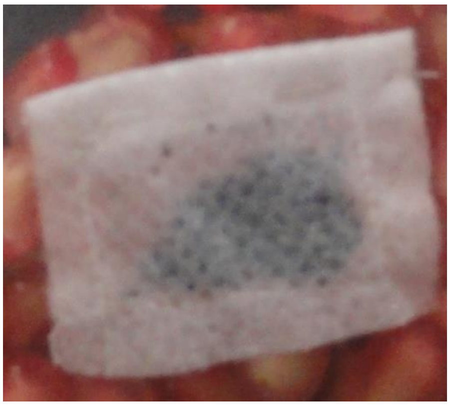


Plate 6. Ethylene absorbent sachet

Permeability of the selected plastic packaging materials used for the experiment were evaluated. Oxygen permeability (oxygen transmission rate) was tested using oxygen permeability tester (OPT-5000) (Plate 6.) and water vapor transmission rate (WVTR) using water vapor permeability tester (L80-5000) (Plate 7.), both from PBI Dansensor, Lyssy Line of Permeability Testers.

Packaging materials	**WVTR (g/m^2/ day)**	**OTR (ml/m^2/ day)**
PP	35.91	2661
LDPE	20.72	2000
Test Standard	ASTM E 398-03	ASTM F 2622-08

In treatments from T_5, T_6, T_7 and T_{10}, cling film of Klin wrap 300 mm of Flexo Film Wraps (India) Ltd., Aurangabad, was tightly wrapped around the trays, in which the fresh fruits and fruit- mix were kept.

Preparation of ethylene absorbent

Muslin cloth sachet of 15cm^2 was made and filled with 1% $KMnO_4$, an ethylene absorbent.

In treatments from T_7 to T_{12}, the prepared ethylene absorbent, $KMnO_4$ sachet was kept inside the packages for absorption of ethylene gas from the package.

In all treatments, except T_5, T_6 , T_{11} and T_{12} , bags were heat sealed using a heat sealing machine (Quick seal ^{TM} of Sevana (India) Ltd. All packaged samples including control were stored under refrigerated condition maintained at 4-5^{0}C.

The following physical, physiological and chemical quality parameters of the treated and packaged fresh- cut fruit samples were recorded at the time of storage and for a period of five days and averaged over five days.

Plate 7. Oxygen permeability tester (OPT-5000)

Plate 8. Water vapor permeability tester (L80-5000)

3.3.1. Physical Parameters

Sensory and visual evaluation was performed by a 10 member semi trained panel to determine the effect of different packaging materials on different physical and sensory attributes by scoring using a nine point hedonic scale as described in 3.2.1.

3.3.2. Physiological parameters

3.3.2. 1. Physiological loss in weight (PLW)

Physiological loss in weight of packaged fresh-cut was calculated over a period of five days.

3.3.2. 2. Percent leakage

Percent leakage of packaged fresh-cut fruits was calculated over a storage period of five days.

3.3.3. Chemical parameters

Chemical parameters of packaged fresh-cut fruits were determined over a storage period of five days.

3.3.3. 1. Acidity

Titratable acidity of packaged fruits was estimated as described in 3.2.3.1 and expressed as per cent anhydrous citric acid.

3.3.3. 2. Total Soluble Solids

Total Soluble Solids of packaged fresh-cut fruits was estimated as described in 3.2.3.2 and expressed in degree brix (^oB)

3.3.3. 3. Starch

Starch content of packaged fresh-cut fruits was estimated as described in 3.2.3.3. and expressed as per cent.

3.3.3. 4. Vitamin C

Vitamin C content of packaged fresh-cut fruits was estimated as described in 3.2.3.4 and expressed as mg/100g of packed cut fruits sample.

3.3.3. 5. Carotenoids

Carotenoids were estimated as described in 3.2.3.5.expressed as mg/100g of fresh- cut fruit.

3.3.3. 6. Total Phenol

Total phenol of the packaged fresh-cut fruits was estimated as described in 3.2.3.6 and expressed as mg/100g of fresh- cut fruit sample.

Based on different physical, chemical and physiological parameters the top ranking four packaging materials were selected for further microbial analysis.

3.3.4. Enumeration of total microbial load

The top four packaging materials showing superior performance in physical, physiological and chemical quality parameters were selected and fruits packaged in those selected packages were subjected to microbial analysis. Microbial count on one gram treated and packaged fruit samples were calculated once in two days for 5days, as described in 3.1.2.

Based on the efficiency in maintaining the microbial populations to the lowest level, the best packaging material was selected for each fresh- cut fruit.

3.3.5. Standardization of best protocol

Combining all the steps like sanitization, pre-storage treatment and packaging best protocol was standardized for each fresh-cut fruit. In the case of fruit mix, each fruit was given the respective sanitization and pre-storage treatment, 25g of each fruit was mixed together to form 100g fruit mix.

3.4. QUALITY PARAMETERS AND ACCEPTABILITY OF THE STANARDIZED PROTOCOL

Fresh- cut fruits and fruit mix were prepared as per the standardized protocol. Physical quality parameters viz., colour and texture of fesh-cut fruits were analysed. Acceptability and cost of production of standardized protocol were worked out.

3.4. 1. Quality parameters

3.4.1.1. Colour

Conventionally, all conceivable colours can be located using Commission Internationale de I’ Enclairage (CIE- The International Commission on Illumination, the primary International Organization concerned with color and color measurement.) *L*a*b** colour space system abbreviated as CIELAB (or CIE L*a*b*, CIE Lab) (McGuire, 1992), which is specified by three perpendicular axes,

*L** - luminance or lightness

*a** - greenness to redness

*b** - blueness to yellowness.

These coordinates pinpoint the measured colour in a three dimensional colour space.

Colour of each fresh- cut fruit prepared using standardized protocol was recorded continuously for five days using spectrophotometer (Plate 8.) using the *L*a*b** color indices, adopted by the Commission Internationale d'Eclairage. The captured images of the products were converted to graphs using computer program from which the colour indices like yellowness index and total colour change were obtained (Mohammadi et al., 2008).

1. **Yellowness index** was computed using the formula

$$\text{Yellowness index} = \frac{142.86 \times (b)}{(L)}$$

Where, b =blueness to yellowness index at the time of observation

L = luminance or lightness index at the time of observation.

2. **Total colour change(difference)** was computed using the formula

$$\text{Total colour change } (\Delta E) = \sqrt{(L_0-L)^2+(a_0-a)^2+(b_0-b)^2}$$

Where L = the degree of lightness to darkness,

L_0 = the initial value of L

a = degree of redness to greenness

a_0 = initial value of a

b = degree of yellowness to blueness

b_0 = initial value of b.

Plate 9. Spectrophotometer assembly for colour measurement

Plate 10. Food texture analyser

3.4.1.2. Textural quality

Instrumental texture profile analysis (TPA) of the prepared fresh- cut fruits was measured continuously for five days using a food texture analyzer (TAHD-Stable Microsystems, UK) (Plate 9.) maintained at following settings by snap test method.

Pre test speed	- 2.00 mm/s
Test speed	- 2.00mm/s
Post test speed	- 2.00 mm/s
Distance	- 50%
Time	- 10 seconds
Temperature	- 25^{0}C

Sample was placed on a heavy duty platform with a crisp support rig in the centre. Papaya fruit pieces were placed with outer portion touching the platform and in pomegranate, ten uniformly sized arils were kept on the platform for analysis. The probe was lowered down to press the sample and a corresponding force deformation curve was plotted. From the TPA curve, the following textural quality parameters of fresh- cut fruits and arils were calculated by the method of Bourne (2002).

1. **Hardness (firmness**) (expressed in Newton-N) which indicates the force required by the probe to crush the fruit piece was obtained at the Y –axis corresponding to highest peak in the graph (Akinbode et al., 2010).

2. **Cohesiveness** - ratio of the positive force areas under the first and second compression

3. **Springiness** - distance by which the fruit piece recovers its height during the time between the end of the first bite and the start of the second bite.

4.Chewiness – energy (Joule) required to masticate the fruit and is the product of hardness, cohesiveness and springiness.

3.4.2. COST OF PRODUCTION

Economics of production of 100 gram fresh- cut fruit and fruit mix, prepared using the standardized protocol was calculated as per the current market rate.

3.4.3. ACCEPTABILITY OF STANDARDIZED TECHNOLOGY

The products were prepared using the standardized protocol and acceptability of the prepared products was tested by conducting sensory evaluation by a 10 member semi trained panel using a nine-point hedonic scale as explained in 3.2.1.

3,5. STATISTICAL ANALYSIS

The observations were analyzed statistically in a Completely Randomized Design (CRD) and significance was tested using analysis of variance technique (Gomez and Gomez, 1984). In organoleptic analysis, the different preferences given by the 10 judges as indicated by scores were evaluated by Kendalls' coefficient of concordance.

Results

4. RESULTS

The experimental data collected from the investigation on "Protocol development for fresh-cut fruits and fruit mix preparation" were analyzed and the results are presented in this chapter under the following headings.

1. Evaluation of different sanitizing agents
2. Evaluation of different pre-storage treatments
3. Development of packaging systems
4. Quality parameters and acceptability of standardized protocol.

4. 1. EVALUATION OF DIFFERENT SANITIZING AGENTS

Four different fruits viz., mango, papaya, pineapple and pomegranate were treated with different sanitizing solutions for 15 minutes and the treated peel pieces were evaluated for microbial count. Analysis of co-variance was conducted for assessing the post treatment effect using pre-treatment as the covariate and the most effective sanitizing solution having maximum efficiency in controlling the microbial organisms was determined for each fruit(Table.1).

4.1.1. Mango

Mango fruits sanitized with 120ppm sodium hypochlorite had least number of bacterial population (5.90 cfu × 10^3) which was on par with the fruits sanitized with 90ppm (9.43 cfu × 10^3) and 60ppm (14.15 cfu × 10^3) sodium hypochlorite solution. Mango fruits sanitized using 40^{o}C water had maximum number of bacterial population (20.88 cfu × 10^3) which was on par with all other treatments except fruits sanitized with 90ppm and 120ppm sodium hypochlorite solution.

Table 1. Bacterial population on fruit surface as influenced surface sanitization

	Bacterial population (cfu × 10^3)			
Treatments	**Mango**	**Papaya**	**Pineapple**	**Pomegranate**
40ºC water	20.88	10.66	21.22	13.46
30ppm sodium hypochlorite	19.12	9.00	16.31	11.33
60ppm sodium hypochlorite	14.15	10.30	14.19	2.27
90ppm sodium hypochlorite	9.43	3.08	11.77	8.00
120ppm sodium hypochlorite	5.90	0.21	5.56	1.39
Control (Washing with Tap water)	20.53	16.06	24.62	14.55
CD (P=0.05%)	10.04	8.2	7.02	10.76

4.1.2. Papaya

Papaya sanitized with 120ppm sodium hypochlorite had least (0.21 cfu × 10^3) number of bacterial load which was on par with samples sanitized with 90ppm sodium hypochlorite solution (3.08 cfu × 10^3). All other treatments including untreated fruits were on par.

4.1.3. Pineapple

Pineapple sanitized with 120ppm sodium hypochlorite had least (5.56 cfu × 10^3) number of bacterial population which was on par with the sample sanitized with 90ppm sodium hypochlorite (11.77cfu × 10^3). Untreated fruits had highest bacterial population (24.62cfu × 10^3) which was on par with pineapple sanitized using 40^{o}C water (21.22 cfu × 10^3).

4.1.4. Pomegranate

Pomegranate sanitized with 120ppm sodium hypochlorite had least number (1.39cfu × 10^3) of bacterial load which was on par with fruits treated with all concentrations of sodium hypochlorite solution. Untreated fruits had highest bacterial population (14.55cfu × 10^3) closely followed by the fungal count on the fruit surface after surface sanitization was very negligible in all the treatments.

Based on the efficiency of sanitizers in reducing the bacterial load on the fruit surface, the following lowest concentrations of sanitizers were selected for further study.

Mango	- 60 ppm sodium hypochlorite solution
Papaya	- 90 ppm sodium hypochlorite solution
Pineapple	- 90 ppm sodium hypochlorite solution
Pomegranate	- 30 ppm sodium hypochlorite solution

4. 2. EVALUATION OF DIFFERENT PRE-STORAGE TREATMENTS

4.2.1. MANGO

4.2.1. 1. Physical Parameters

Effect of different pre-storage treatments on physical quality parameters of fresh- cut mango pieces, as judged by sensory scoring (averaged over five days) is shown in Table 2.

Cut mango pieces treated with 1% Calcium Ascorbate had scored maximum for flavour (6.20), taste (6.55) and overall acceptability (6.80). Calcium chloride treated fruit pieces obtained maximum score for appearance(7.13), texture (6.70) and juiciness (6.00). Overall acceptability was highest (6.80) for mango pieces treated with 0.1% KMS + 0.1% citric acid. Highest score for juiciness (6.00) was obtained for mango pieces treated with 0.1% sodium benzoate + 0.1% ascorbic acid. Sodium Acid Sulphate (3%) treated mango pieces though scored maximum for colour, it had least score for texture (2.35), taste (1.25) and juiciness (1.80).

4.2.1. 2. Physiological parameters

Effect of different pre-storage treatments on physiological parameters of fresh- cut mango pieces is shown in Table 3.

4.2.1. 2. 1. Physiological loss in weight (PLW)

Physiological loss in weight was least for the sample treated with 0.1% sodium benzoate+citric acid (4.56), which was on par with all other treated fresh- cut fruit pieces (Table 3.). The untreated fresh- cut mango pieces recorded the highest(7.83) physiological loss in weight.

Table 2. Effect of pre-storage treatments on physical quality parameters of fresh-cut mango

Pre-storage treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
0.1% KMS + 0.1% Ascorbic acid	4.63	2.35	5.20	4.45	5.90	5.00	2.70
0.1% KMS + 0.1% Citric acid	4.50	4.30	4.85	2.65	6.25	5.00	6.80
0.1% Sodium benzoate + 0.1% ascorbic acid	3.13	3.10	4.25	4.30	3.50	6.00	5.30
0.1% Sodium benzoate + 0.1% Citric acid	5.13	4.50	3.35	6.25	4.40	5.60	2.60
Calcium Chloride (1%)	7.13	4.75	5.10	6.70	3.95	6.00	6.10
Calcium Ascorbate (1%)	6.75	3.30	6.20	6.65	6.55	4.70	6.80
Sodium Acid Sulphate (3%)	2.13	6.85	4.80	2.35	1.25	1.80	3.40
Control (Without any Treatment)	2.63	6.85	2.25	2.65	4.20	1.90	2.30
Kendalls W (a)	0.648	0.639	0.351	0.731	0.592	0.657	0.713
Assymp. Syg	0.011	0.000	0.001	0.000	0.000	0.000	0.000

a- Kendall’s coefficient of concordance

Table 3. Effect of pre-storage treatments on physiological quality parameters of fresh-cut mango

Treatments	Physiological loss in weight (%)	Osmotic potential	Percentage leakage(%)
0.1% KMS and 0.1% ascorbic acid	4.74	-1051.00	92.99
0.1% KMS and 0.1% citric acid	5.04	-695.50	90.98
0.1% Sodium benzoate and 0.1% ascorbic acid	5.27	-864.75	90.28
0.1% Sodium benzoate and 0.1% citric acid	4.56	-914.50	85.46
Calcium chloride (1%)	5.80	-683.25	80.33
Calcium Ascorbate (1%)	4.60	-633.00	87.11
Sodium Acid Sulphate (3%)	6.90	-677.75	91.30
Control (Without any Treatment)	7.83	-605.50	93.86
CD (P=0.05%)	2.99	117.28	3.72

4.2.1.2.2. Osmotic potential

Osmotic potential was least for the untreated fresh- cut mango pieces (-605.50) which was on par with all the samples except those pieces treated with sodium benzoate+ascorbic acid (0.1%) , sodium benzoate+ citric acid (0.1%) and KMS+ ascorbic acid (0.1%)(Table 3.). Osmotic potential was highest for the fresh-cut fruit sample treated with KMS+ascorbic acid (-1051.00), followed by the sample treated with 0.1% sodium benzoate+ citric acid (-914.50), which was on par with sample treated with sodium benzoate+ascorbic acid(-864.75).

4.2.1.2.3. Percent leakage

Percent leakage was least for the fresh- cut mango pieces, treated with 1% calcium chloride (80.33), followed by the sample treated with 0.1% sodium benzoate and citric acid (85.46), which was on par with sample treated with 1% calcium ascorbate (87.11). Highest percent leakage was for the untreated sample (93.86) which was on par with the samples treated with 0.1% KMS+ascorbic acid (92.99), sodium acid sulphate(91.30), 0.1% KMS+0.1% citric acid (90.98) and 0.1% sodium benzoate+ 0.1% ascorbic acid (90.28) (Table 3.).

4.2.1. 3. Chemical quality parameters

Effect of different pre-storae treatments on chemical quality parameters of fresh- cut mango pieces averaged over a period of five days of storage is shown in Table 4.

4.2.1. 3.1. Acidity

Fresh- cut mango pieces treated with 0.1% KMS+ citric acid exhibited least (0.41%) acidity value followed by sample treated with 0.1% KMS+ ascorbic acid (0.59%) (Table 4.). Acidity was maximum (1.04%) for fruit pieces treated with

Table 4. Effect of pre-storage treatments on chemical quality parameters of fresh-cut mango

Treatments	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit. C (mg/ 100g)	Carotenoid (mg/100g)	Total phenol (mg/100g)
0.1% KMS + 0.1% ascorbic acid	0.59	6.54	12.79	18.99	0.001	37.00
0.1% KMS + 0.1% Citric acid	0.41	7.15	15.00	17.05	0.001	33.90
0.1% Sodium benzoate + 0.1% ascorbic acid	1.04	6.65	18.64	16.09	0.002	33.34
0.1% Sodium benzoate + 0.1% Citric acid	0.92	6.69	13.61	14.24	0.005	33.47
Calcium Chloride (1%)	0.71	6.65	13.53	17.50	0.003	33.16
Calcium Ascorbate (1%)	0.69	7.25	16.18	27.82	0.006	33.99
Sodium Acid Sulphate (3%)	0.89	6.40	11.28	17.00	0.006	30.36
Control (Without any Treatment)	0.97	7.64	10.58	14.05	0.004	30.89
CD (P=0.05%)	0.07	0.59	0.47	1.75	0.0005	1.73

0.1% sodium benzoate + ascorbic acid which was on par with untreated mango pieces (0.97).

4.2.1.3.2. Total Soluble Solids

Total Soluble Solids (TSS) was the highest for the untreated mango pieces (7.64^{0}brix) which was on par with samples treated with calcium ascorbate(7.25^{0}B) and 0.1% KMS+citric acid(7.15) (Table 4.). TSS was least for the mango pieces treated with sodium acid sulphate (6.40^{0}B) which was on par with the fresh- cut mango pieces treated with all other chemicals except those with lowest TSS.

4.2.1.3.3. Starch

Starch content was the highest for the sample treated with 0.1% sodium benzoate+ ascorbic acid (18.64%), followed by the sample treated with 1% calcium ascorbate (16.18%). Starch content was the least for the untreated mango pieces (10.58%), followed by the sample treated with sodium acid sulphate (11.28%) (Table 4.).

4.2.1. 3.4. Vitamin C

Highest vitamin C content was exhibited by the fresh- cut mango pieces treated with1% calcium ascorbate (27.82) followed by sample treated with 0.1% KMS+ ascorbic acid (18.99) (Table 4.). Vitamin C content was the lowest for the untreated cut mango pieces(14.05) which was on par with sample treated with 0.1% sodium benzoate+citric acid(14.24).

4.2.1. 3.5. Carotenoid

Total carotenoid was the highest (0.006) for cut mango pieces treated with 3% sodium acid sulphate and 1% calcium ascorbate. Total carotenoid content was the least

(0.001) for the mango pieces treated with 0.1% KMS+ascorbic acid and 0.1% KMS+citric acid(Table 4.).

4.2.1. 3.6. Total phenol

Total phenol was the minimum for the cut mango pieces treated with 3% sodium acid sulphate (30.36), which was on par with the untreated sample (30.89) (Table 4.). Total phenol was the highest (37.00) for the mango pieces treated with 0.1% KMS+ascorbic acid.

4.2.2. PAPAYA

4.2.2. 1. Physical Parameters

Effect of different pre-storage treatments on physical quality parameters of fresh- cut papaya pieces, as judged by sensory scoring (averaged over five days) is shown in Table 5. Cut papaya pieces treated with 1% Calcium Ascorbate had scored highest value for flavour (6.60), taste (6.45) and juiciness (6.55). Cut papaya pieces treated with calcium chloride had highest score for texture (6.55) and overall acceptability (6.50). Papaya pieces treated with 0.1% KMS + 0.1% citric acid had highest score (6.10)for appearance.

4.2.2. 2. Physiological parameters

Effect of different pre-storage treatments on physiological quality parameters of fresh- cut papaya pieces averaged over five days of storage is shown in Table 6.

Table 5. Effect of pre-storage treatments on physical quality parameters of fresh-cut papaya

Pre-storage treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
0.1% KMS + 0.1% Ascorbic acid	4.70	4.35	5.60	4.75	5.80	6.20	6.10
0.1% KMS + 0.1% Citric acid	6.10	4.70	5.25	5.55	6.05	6.15	6.00
0.1% Sodium benzoate + 0.1% ascorbic acid	3.80	3.70	4.65	3.90	3.25	3.00	2.60
0.1% Sodium benzoate + 0.1% Citric acid	4.95	4.90	3.80	5.85	4.20	4.10	4.25
Calcium Chloride (1%)	5.00	3.00	5.50	6.55	4.85	5.65	6.50
Calcium Ascorbate (1%)	3.80	1.50	6.60	3.40	6.45	6.55	6.30
Sodium Acid Sulphate (3%)	3.70	7.05	1.90	3.35	1.25	1.70	2.55
Control (Without any Treatment)	3.95	6.80	2.70	2.65	4.15	2.65	1.70
Kendalls W [a]	0.171	0.691	0.544	0.393	0.574	0.676	0.714
Assymp Syg	0.102	0.000	0.000	0.000	0.000	0.000	0.000

a- Kendalls coefficient of concordance

Table 6. Effect of pre-storage treatments on physiological quality parameters of fresh-cut papaya

Treatments	Physiological loss in weight (%)	Osmotic potential	Percentage leakage (%)
0.1% KMS + 0.1% Ascorbic acid	4.43	-1239.00	83.55
0.1% KMS + 0.1% Citric acid	3.62	-1171.50	89.88
0.1% Sodium benzoate + 0.1% ascorbic acid	4.90	-1209.50	94.20
0.1% Sodium benzoate + 0.1% Citric acid	3.98	-1397.95	93.26
Calcium Chloride (1%)	3.95	-1325.25	85.78
Calcium Ascorbate (1%)	5.04	-1233.50	93.30
Sodium Acid Sulphate (3%)	4.89	-1167.50	79.45
Control (Without any Treatment)	5.38	-1215.25	91.82
CD (P=0.05%)	1.35	229.39	5.70

4.2.2. 2. 1. Physiological loss in weight (PLW)

Physiological loss in weight was least for sample treated with 0.1% KMS + 0.1% citric acid (3.62%) which was on par with other samples except samples treated with 1% calcium ascorbate (5.04%) and untreated fruit pieces(5.38%) (Table 6).

4.2.2. 2. 2.Osmotic potential

Osmotic potential was highest for fruit pieces treated with 0.1% Sodium benzoate + 0.1% Citric acid (-1397.95) which was on par with other samples except those treated with 3% Sodium Acid Sulphate (-1167.5) which had the lowest value (Table 6).

4.2.2.2.3. Percent leakage

Percent leakage was least for the sample treated with 3%Sodium Acid Sulphate (79.45%) which was on par with sample treated with 0.1% KMS + 0.1% Ascorbic acid (83.55%) (Table 6). Percentage leakage was highest for sample treated with 0.1% Sodium benzoate + 0.1% ascorbic acid (94.20%) which was on par with all other samples except the samples treated with 3% Sodium Acid Sulphate and 0.1% KMS + 0.1% Citric acid.

4.2.2.3. Chemical quality parameters

Effect of different pre treatments on chemical quality parameters of fresh- cut papaya pieces averaged over a period of five days is shown in Table 7.

4.2.2. 3.1. Acidity

Acidity was least for fresh- cut papaya pieces treated with 0.1% Sodium benzoate + 0.1% ascorbic acid and 1% Calcium Chloride (0.068) which was on par with all other samples except fruit sample treated with 3% Sodium Acid Sulphate (0.093) which had the highest acidity value (Table 7).

Table 7. Effect of pre-storage treatments on chemical quality parameters of fresh-cut papaya

Treatments	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit. C (mg/100g)	Carotenoids (mg/100g)	Toal Phenol (mg/100g)
0.1% KMS + 0.1% Ascorbic acid	0.070	6.14	8.90	30.90	0.003	23.05
0.1% KMS + 0.1% Citric acid	0.072	6.43	10.28	26.72	0.005	23.17
0.1% Sodium benzoate + 0.1% ascorbic acid	0.068	6.02	10.04	28.41	0.029	22.62
0.1% Sodium benzoate + 0.1% Citric acid	0.070	5.80	11.95	26.59	0.007	23.38
Calcium Chloride (1%)	0.068	6.29	11.80	24.73	0.004	26.21
Calcium Ascorbate (1%)	0.074	6.13	11.76	36.43	0.004	26.85
Sodium Acid Sulphate (3%)	0.093	5.97	9.24	21.78	0.045	21.59
Control (Without any Treatment)	0.074	8.70	9.45	21.15	0.003	21.01
CD (P=0.05%)	0.014	0.45	0.0024	3.38	0.0025	0.73

4.2.2. 3.2. Total Soluble Solids

Total Soluble Solids was highest for untreated cut papaya pieces (8.70) (Table 7). Total Soluble Solids was lowest for cut papaya pieces treated with 3% Sodium Acid Sulphate (5.97) which was on par with all other fruit pieces except those treated with 0.1% KMS + 0.1% ascorbic acid(6.43).

4.2.2. 3.3. Starch

Starch content was highest for the cut papaya sample treated with 0.1% Sodium benzoate + 0.1% citric acid(11.95) followed by papaya samples treated with 1% calcium chloride (11.80) and 1% calcium ascorbate(11.76). Starch content was least for cut papaya treated with 0.1% KMS + 0.1% ascorbic acid (8.90) (Table 7).

4.2.2. 3.4. Vitamin C

Vitamin C content was highest for the sample treated with 1% Calcium ascorbate(36.43) followed by samples treated with 0.1% KMS + 0.1% ascorbic acid (30.90) which was on par with sample treated with 0.1% Sodium benzoate + 0.1% ascorbic acid (28.41) (Table 7). Vitamin C content was the lowest for the untreated papaya pieces (21.15) which was on par with sample treated with 3% Sodium Acid Sulphate (21.78).

4.2.2. 3.5. Carotenoids

Highest carotenoids were for fresh- cut papaya pieces treated with 3% Sodium Acid Sulphate (0.045), followed by samples treated with 0.1% sodium benzoate + 0.1% ascorbic acid (0.029). Lowest carotenoid was observed in papaya pieces treated with 0.1% KMS + 0.1% ascorbic acid (0.003) and in untreated papaya pieces, which was on par with all the samples except those treated with 3% sodium acid sulphate (0.045), 0.1% sodium benzoate + 0.1% ascorbic acid (0.029) and 0.1% sodium benzoate + 0.1% citric acid(0.007) (Table 7).

4.2.2. 3.6. Total phenol

Total phenol was least for the untreated cut papaya pieces (21.01) which was on par with the sample treated with 3% Sodium Acid Sulphate (21.59) (Table 7). Maximum total phenol was seen in papaya fruit pieces treated with 1% calcium ascorbate (26.85) which was on par with fruit pieces treated with 1% calcium chloride (26.21).

4.2.3. PINEAPPLE

4.2.3. 1. Physical Parameters

Effect of different pre-storage treatments on physical quality parameters of fresh- cut pineapple pieces, as judged by sensory scoring (averaged over five days) is shown in Table 8.

Pineapple pieces treated with 0.1% KMS + 0.1% citric acid had obtained highest score for appearance (6.60) and overall acceptability(6.30). Cut pineapple pieces treated with 1% calcium ascorbate had highest score for taste(6.50) and juiciness(6.45). Sodium Acid Sulphate treated fruit pieces had highest score for colour (6.85) and flavour (5.85). Untreated pineapple pieces had obtained least score for appearance(1.15), taste(1.35), juiciness(1.90) and overall acceptability(1.50).

4.2.3. 2. Physiological parameters

Effect of different pre-storage treatments on physiological parameters of fresh- cut pineapple pieces averaged over five days is shown in Table 9.

Table 8. Effect of pre-storage treatments on physical quality parameters of fresh-cut pineapple

Pre-treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
0.1% KMS + 0.1% Ascorbic acid	5.20	4.95	3.10	5.85	3.25	2.65	3.25
0.1% KMS + 0.1% Citric acid	6.60	5.60	5.70	5.05	4.65	6.00	6.30
0.1% Sodium benzoate + 0.1% ascorbic acid	6.25	4.00	5.25	2.75	6.15	6.35	6.25
0.1% Sodium benzoate + 0.1% Citric acid	3.30	2.60	2.75	4.00	3.10	3.30	2.60
Calcium Chloride (1%)	5.75	4.75	5.40	4.75	6.20	6.35	6.05
Calcium Ascorbate (1%)	4.20	3.25	4.90	2.50	6.50	6.45	5.90
Sodium Acid Sulphate (3%)	3.55	6.85	5.85	6.30	3.00	3.00	4.15
Control (Without any Treatment)	1.15	4.00	3.05	4.80	1.35	1.90	1.50
Kendalls W [(a)]	0.585	0.339	0.311	0.335	0.718	0.677	0.626
Assymp Syg	0.000	0.001	0.003	0.001	0.000	0.000	0.000

a- Kendalls coefficient of concordance

Table 9. Effect of pre-storage treatments on physiological parameters of fresh-cut pineapple

Treatments	Physiological loss in weight (%)	Osmotic potential	Percentage leakage (%)
0.1% KMS + 0.1% Ascorbic acid	3.60	-1630.75	91.15
0.1% KMS + 0.1% Citric acid	3.17	-1675.75	83.94
0.1% Sodium benzoate + 0.1% ascorbic acid	4.04	-1433.00	91.06
0.1% Sodium benzoate + 0.1% Citric acid	3.81	-1626.95	87.41
Calcium Chloride (1%)	2.05	-1484.25	82.39
Calcium Ascorbate (1%)	3.34	-1427.25	85.84
Sodium Acid Sulphate (3%)	3.47	-1619.05	89.37
Control (Without any Treatment)	2.73	-1476.75	92.34
CD (P=0.05%)	0.954	NS	3.96

4.2.3.2.1. Physiological loss in weight (PLW)

Physiological loss in weight was minimum for fresh- cut pineapple pieces treated with calcium chloride (2.05) which was on par with untreated cut pineapple pieces (2.73) (Table 9). Physiological loss in weight was maximum for pineapple pieces treated with 0.1% sodium benzoate + 0.1% ascorbic acid (4.04), which was on par with all other fresh- cut pineapple pieces except those pieces treated with calcium chloride and untreated samples.

4.2.3. 2. 2. Osmotic potential

All the pine apple samples whether treated or untreated had similar osmotic potential (Table 9).

4.2.3.2.3. Percent leakage

Percent leakage was least for fresh- cut pineapple pieces treated with calcium chloride (82.39) which was on par with samples treated with 0.1% KMS and 0.1% citric acid (83.94) and calcium ascorbate (85.84) (Table 9). Highest percent leakage was for untreated cut pineapple pieces (92.34) which was on par with samples treated with 0.1% KMS and 0.1% ascorbic acid (91.15), 0.1% sodium benzoate + 0.1% ascorbic acid (91.06) and those treated with 3% sodium acid sulphate (89.37).

4.2.3. 3. Chemical quality parameters

Effect of different pre-storage treatments on chemical quality parameters of fresh- cut pineapple averaged over five days is shown in Table 10.

Table 10. Effect of pre-storage treatments on chemical quality parameters of fresh-cut pineapple

Treatments	**Acidity (%)**	**TSS (^{0}B)**	**Starch (%)**	**Vit. C (mg/100g)**	**Carotenoids (mg/100g)**	**Total phenol (mg/100g)**
0.1% KMS + 0.1% Ascorbic acid	0.128	7.70	10.48	26.84	0.001	35.80
0.1% KMS + 0.1% Citric acid	0.146	9.77	10.32	30.16	0.002	33.76
0.1% Sodium benzoate + 0.1% ascorbic acid	0.129	9.72	9.75	30.91	0.003	31.65
0.1% Sodium benzoate + 0.1% Citric acid	0.131	8.53	9.82	28.72	0.002	31.40
Calcium Chloride (1%)	0.138	9.00	9.93	32.33	0.001	35.31
Calcium Ascorbate (1%)	0.143	10.60	10.21	43.99	0.002	37.79
Sodium Acid Sulphate (3%)	0.122	10.20	8.54	32.11	0.002	28.80
Control (Without any Treatment)	0.121	13.10	9.61	26.11	0.001	32.14
CD (P=0.05%)	0.021	0.997	0.58	3.93	0.00028	2.09

4.2.3. 3.1. Acidity

Untreated cut pineapple pieces were least (0.121) acidic, which was on par with pieces treated with all other chemicals except those with 1% calcium ascorbate (0.143) and 0.1% KMS and 0.1% citric acid(0.146) (Table 14.). Pine apple pieces treated with 0.1% KMS and 0.1% citric acid had highest acidity (0.146).

4.2.3. 3.2. Total Soluble Solids

Untreated cut pine apple pieces had the highest Total Soluble Solids (13.1^{0}B) followed by cut pieces treated with 1% calcium ascorbate(10.6^{0}B). Sample treated with 0.1% KMS and 0.1% ascorbic acid had the lowest Total Soluble Solids (7.70^{0}B) which was on par with pine apple pieces treated with 0.1% Sodium benzoate + 0.1% citric acid(8.53^{0}B) (Table 10.).

4.2.3. 3.3. Starch

Fresh- cut pine apple pieces treated with 0.1% KMS and 0.1% ascorbic acid had highest starch (10.48) content which was on par with samples treated with 0.1% KMS and 0.1% citric acid(10.32), calcium ascorbate(10.21) and with 1% calcium chloride (9.93). Starch content was the least for cut pine apple pieces treated with 3% sodium acid sulphate (8.54) (Table 10.).

4.2.3. 3.4. Vitamin C

Pineapple pieces treated with 1% calcium ascorbate had the highest vitamin C (43.99) followed by samples treated with calcium chloride (32.33) (Table 10.). Untreated fresh- cut pine apple pieces had lowest vitamin C (26.11) which was on par with samples treated with 0.1% KMS and 0.1% Ascorbic acid (26.84) and 0.1% sodium benzoate+ 0.1% citric acid (28.72).

4.2.3.3.5. Carotenoid

Fresh- cut pineapple pieces treated with 0.1% sodium benzoate+ 0.1% ascorbic acid had highest carotenoid content (0.003). Untreated cut pieces, samples treated with 0.1% KMS and 0.1% ascorbic acid and those treated with 1% calcium chloride had lowest (0.001) carotenoid content(Table 10.).

4.2.3. 3.6. Total phenol

Total phenol was least for fresh- cut pine apple pieces treated with 3% sodium acid sulphate (28.80) followed by samples treated with 0.1% sodium benzoate+ 0.1% citric acid (31.4), which was on par with those treated with 0.1% sodium benzoate+ 0.1% ascorbic acid (31.65) and untreated pieces (32.14) (Table 10.). Phenol content was highest for pine apple pieces treated with 1% calcium ascorbate (37.79), which was on par with sample treated with 0.1% KMS and 0.1% ascorbic acid (35.8).

4.2.4. POMEGRANATE

4.2.4. 1. Physical Parameters

Effect of different pre-storage treatments on physical quality parameters of pomegranate arils, as judged by sensory scoring(averaged over five days) is shown in Table 11.

Pomegranate arils treated with 0.1% KMS + 0.1% ascorbic acid scored highest for appearance (6.05), flavour (6.20), taste (6.40) and overall acceptability (6.40). Arils treated with 0.1% sodium benzoate + 0.1% citric acid had highest score for texture (6.40) and untreated pomegranate arils recorded highest score for colour (6.30).

Table 11. Effect of pre-storage treatments on physical quality parameters of pomegranate arils

Pre-storage treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
0.1% KMS + 0.1% ascorbic acid	6.05	6.10	6.20	6.05	6.40	5.95	6.40
0.1% KMS + 0.1% citric acid	4.85	4.90	3.80	4.30	4.10	4.35	4.45
0.1% sodium benzoate + 0.1% ascorbic acid	3.55	3.30	3.60	3.55	4.30	4.75	3.45
0.1% sodium benzoate + 0.1% Citric acid	5.10	3.25	5.70	6.40	5.50	5.25	4.65
Calcium chloride (1%)	3.90	4.50	5.75	5.55	5.45	6.20	6.00
Calcium ascorbate (1%)	2.75	3.65	6.10	6.35	5.80	5.20	6.10
Sodium acid sulphate (3%)	4.20	4.00	2.15	1.20	1.50	2.00	2.25
Control (Without any Treatment)	5.60	6.30	2.70	2.60	2.95	2.30	2.70
Kendalls W[(a)]	0.219	0.252	0.521	0.659	0.543	0.483	0.550
Assymp Syg	0.032	0.014	0.000	0.000	0.000	0.000	0.000

a- Kendalls coefficient of concordance

4.2.4. 2. Physiological parameters

Effect of different pre-storage treatments on physiological parameters of pomegranate arils averaged over five days is shown in Table 12.

4.2.4.2.1. Physiological loss in weight (PLW)

Physiological loss in weight was least for the pomegranate arils treated with 1% calcium chloride (1.60) which was on par with all arils except arils treated with 3% Sodium Acid Sulphate and untreated arils (Table 12). Pomegranate arils treated with 3% Sodium Acid Sulphate had highest physiological loss in weight (6.74%) which was on par with the untreated arils (5.03).

4.2.4. 2. 2. Osmotic potential

Osmotic potential was highest for the pomegranate arils treated with 3% Sodium Acid Sulphate (-2523.95) followed by the arils treated with 0.1% KMS + 0.1% citric acid (-2058.00). Lowest osmotic potential was for the pomegranate arils treated with 1% calcium chloride (-1724.00) which was on par with all arils except those treated with Sodium Acid Sulphate and 0.1% KMS + 0.1% citric acid(Table 12)..

4.2.4. 2. 3. Percent leakage

Percent leakage was least for the pomegranate arils treated with 1% calcium chloride (61.09) which was on par with all arils, except those treated with 0.1% KMS + 0.1% citric acid and 3% sodium acid sulphate(Table 12).. Pomegranate arils treated with 3% sodium acid sulphate had highest percentage leakage (89.35) followed by samples treated with 0.1% KMS + 0.1% citric acid (70.92).

Table 12. Effect of pre-storage treatments on physiological parameters of pomegranate arils

Treatments	Physiological loss in weight (%)	Osmotic potential	Percent leakage (%)
0.1% KMS + 0.1% Ascorbic acid	2.66	-1829.40	61.50
0.1% KMS + 0.1% Citric acid	2.26	-2058.00	70.92
0.1% Sodium benzoate + 0.1% ascorbic acid	2.32	-1729.50	61.78
0.1% Sodium benzoate + 0.1% Citric acid	1.96	-1820.75	64.61
Calcium Chloride (1%)	1.60	-1724.00	61.09
Calcium Ascorbate (1%)	2.93	-1843.25	62.44
Sodium Acid Sulphate (3%)	6.74	-2523.95	89.35
Control (Without any Treatment)	5.03	-1788.50	66.89
CD (P=0.05%)	1.96	214.30	6.03

4.2.4. 3. Chemical quality parameters

Effect of different pre-storage treatments on chemical quality parameters of pomegranate arils averaged over five days is shown in Table 13.

4.2.4. 3.1. Acidity

Pomegranate arils treated with 0.1% KMS + 0.1% citric acid had least acidity value (0.05) which was on par with all other samples except arils treated with 3% sodium acid sulphate (0.066) (Table 13).

4.2.4. 3.2. Total Soluble Solids

Highest Total Soluble Solids was for the pomegranate arils treated with 3% sodium acid sulphate (16.09) which was on par with the untreated arils (15.81) and arils treated with 1% calcium ascorbate (15.60). Arils treated with 0.1% KMS + 0.1% ascorbic acid had least TSS(14.64) which was on par with arils treated with 0.1% KMS + 0.1% citric acid(14.76), 1% calcium chloride (14.9), 0.1% Sodium benzoate + 0.1% ascorbic acid(15.04) and 0.1% sodium benzoate + 0.1% citric acid(15.17) (Table 13).

4.2.4. 3.3. Starch

Pomegranate arils treated with 1% calcium ascorbate had maximum starch content (18.48) followed by the arils treated with 0.1% KMS + 0.1% ascorbic acid (16.42) (Table 13). Starch content was lowest for the arils treated with 3% sodium acid sulphate (14.38) which was on par with the untreated arils (15.29).

4.2.4. 3.4. Vitamin C

Pomegranate arils treated with 1% calcium ascorbate had highest vitamin C content(46.25) followed by sample treated with 0.1% sodium benzoate+ 0.1% ascorbic

Table 13. Effect of pre-storage treatments on chemical quality parameters of pomegranate arils

Treatments	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit. C (mg/100g)	Carotenoids (mg/100g)	Total phenol (mg/100g)
0.1% KMS + 0.1% Ascorbic acid	0.055	14.64	16.42	42.13	0.007	192.20
0.1% KMS + 0.1% Citric acid	0.050	14.76	15.70	42.80	0.003	209.4
0.1% Sodium benzoate + 0.1% ascorbic acid	0.060	15.04	15.69	44.60	0.003	215.20
0.1% Sodium benzoate + 0.1% Citric acid	0.051	15.17	15.75	40.30	0.005	201.02
Calcium Chloride (1%)	0.050	14.90	15.45	43.27	0.004	205.82
Calcium Ascorbate (1%)	0.050	15.60	18.48	46.25	0.003	217.58
Sodium Acid Sulphate (3%)	0.066	16.09	14.38	40.19	0.004	185.50
Control (Without any Treatment)	0.050	15.81	15.29	40.13	0.002	182.09
CD(P=0.05%)	0.010	0.57	1.03	1.61	0.0003	15.69

acid(44.60). Vitamin C content was least in untreated arils (40.13) which was on par with samples treated with 3% sodium acid sulphate (40.19) and 0.1% sodium benzoate+ 0.1% citric acid(40.30) (Table 13).

4.2.4. 3.5. Carotenoids

Highest total carotenoid content was for the pomegranate arils treated with 0.1% KMS + 0.1% ascorbic acid(0.007), followed by samples treated with 0.1% sodium benzoate+ 0.1% citric acid(0.005). Least total carotenoid was obtained for untreated arils (0.002) (Table 13).

4.2.4. 3.6. Total phenol

Total phenol was least for the untreated pomegranate arils (182.09), which was on par with arils treated with 3% sodium acid sulphate (185.50) and 0.1% KMS + 0.1% ascorbic acid(192.2). Highest phenol was seen in pomegranate arils treated with 1% calcium ascorbate (217.58) (Table 13), which was on par with arils treated with 1% calcium chloride(205.82)

4.2.5. CALCULATION OF WEIGHTED AVERAGE RANKS

As none of the pre- treatments tried showed superior performance for all the quality parameters evaluated, the four pre-treatments having top weighted average ranks were selected for each fruit, for further microbial analysis. In cut papaya pieces, the physiological parameters were also considered before finalizing the four efficient and economic pre-treatments.

Pre-treatments having top weighted average ranks			
Fresh- cut mango pieces	Fresh- cut papaya pieces	Fresh- cut pineapple pieces	Pomegranate arils
0.1% KMS and 0.1%	0.1% KMS + 0.1%	0.1% KMS and 0.1%	0.1% KMS + 0.1%

citric acid	Ascorbic acid	citric acid	ascorbic acid
0.1% Sodium benzoate and 0.1% ascorbic acid	0.1% KMS + 0.1% Citric acid	0.1% Sodium benzoate and 0.1% ascorbic acid	0.1% Sodium benzoate and 0.1% citric acid
Calcium Chloride (1%)	Calcium Chloride (1%)	Calcium Chloride (1%)	Calcium Chloride (1%)
Calcium Ascorbate (1%)	Calcium Ascorbate (1%)	Calcium Ascorbate (1%)	Calcium Ascorbate (1%)

4.2.6. ENUMERATION OF TOTAL MICROBIAL LOAD

4.2.6.1. MANGO

When microbial count on the fresh- cut mango fruits treated with selected pre treatments was analysed, bacterial population was same for all the cut pieces (Table14). Fungal count was minimum (2.50cfu x 10^3) on cut fruits treated with 0.1% KMS and 0.1% citric acid. All other treatments resulted in similar fungal count on fresh- cut mango pieces.

4.2.6.2. PAPAYA

In fresh- cut papaya pieces, bacterial and fungal population were same for all the samples (Table14.). Hence, considering the physiological parameters also combination of 0.1% KMS and 0.1% citric acid was selected as the efficient pre-treatment for fresh- cut papaya pieces.

4.2.6.3. PINEAPPLE

The fungal population was same for all the fresh- cut pineapple pieces (Table 14). Bacterial count was minimum (12 cfu x 10^3) on cut fruits treated with 0.1% sodium benzoate+ 0.1% ascorbic acid, which was on par with fruits treated with 1% calcium chloride (18.67cfu x 10^3) and 0.1% KMS + 0.1% citric acid(20.33 cfu x 10^3). Bacterial count was highest (65 cfu x 10^3) on fruits treated with 1% Calcium ascorbate. When physiological quality parameters were also considered, 1% Calcium Chloride had low

Table 14. Microbial count on fresh-cut fruits treated with selected pre-storage treatments

Pre-storage treatments	Bacterial count ($x10^3$)	Fungal count ($x10^3$)
MANGO*		
0.1% KMS and 0.1% citric acid	25.50 (4.92)	2.50 (1.63)
0.1% sodium benzoate and 0.1% ascorbic acid	76.50 (7.54)	7.17 (2.70)
Calcium chloride (1%)	23.83(5.06)	6.83 (2.42)
Calcium ascorbate (1%)	25.67 (4.98)	5.67 (2.32)
CD(P=0.05%)	NS	0.67
PAPAYA **		
0.1% KMS + 0.1% ascorbic acid	33.17 (1.49)	4.67 (0.74)
0.1% KMS + 0.1% citric acid	124.17 (1.70)	5.67 (0.70)
Calcium chloride (1%)	41.17 (1.52)	7.00 (0.80)
Calcium ascorbate (1%)	29.33 (1.40)	9.00 (0.87)
CD(P=0.05%)	NS	NS
PINEAPPLE**		
0.1% KMS and 0.1% citric acid	20.33 (1.28)	6.83 (0.77)
0.1% sodium benzoate and 0.1% ascorbic acid	12.20 (1.05)	4.67 (0.71)
Calcium chloride (1%)	18.67 (1. 20)	6.50 (0.71)
Calcium ascorbate (1%)	65.00 (1.46)	5.67 (0.69)
CD(P=0.05%)	0.38	NS
POMEGRANATE*		
0.1% KMS + 0.1% ascorbic acid	14.33 (3.56)	0.50 (0.94)
0.1% sodium benzoate and 0.1% citric acid	63.00 (6.03)	2.16 (1.53)
Calcium chloride (1%)	11.83 (3. 06)	1.00 (1.16)
Calcium ascorbate (1%)	3.17 (1.65)	0.83 (1.09)
CD(P=0.05%)	2.73	0.36

*- Values in parenthesis show square root transformed values
**- Values in parenthesis show logarithmic transformed values

physiological loss in weight and percentage leakage compared to 0.1% Sodium benzoate + 0.1% ascorbic acid (Table14.), hence selected for further study.

4.2.6.4. POMEGRANATE

When microbial count on the arils treated with selected pre treatments was analysed, bacterial and fungal population were same for all the samples except those treated with 0.1% sodium benzoate + 0.1% citric acid (Table 21.). Bacterial (63 cfu x 10^3) and fungal (2.16 cfu x 10^3) count were maximum on cut fruits treated with 0.1% sodium benzoate+ 0.1% citric acid. When physical quality parameters were also considered 1% calcium chloride had superior quality parameters compared to 0.1% KMS + 0.1% ascorbic acid (Table 14.).

Most efficient pre-treatment having capacity to maintain the physical, physiological and chemical quality parameters and to reduce the microbial population of fresh- cut fruit pieces, stored under ambient condition, was selected as the efficient pre- treatment for each fresh- cut fruit piece.

Fresh- cut mango pieces	- 0.1% KMS and 0.1% citric acid
Cut papaya pieces	- 0.1% KMS and 0.1% citric acid
Cut pineapple pieces	- 1% calcium chloride
Pomegranate arils	- 1% calcium chloride

4. 3. DEVELOPMENT OF PACKAGING SYSTEM

Physical, physiological and chemical parameters of the fresh-cut fruits kept in different packaging materials after subjecting to following sanitization and pre-storage treatments (as shown below), were recorded at the time of storage and for a period of five days.

Fruits	Selected treatments	
	Sanitization	Pre-treatment
Mango	60 ppm sodium hypochlorite solution	0.1% KMS and 0.1% citric acid
Papaya	90 ppm sodium hypochlorite solution	0.1% KMS and 0.1% citric acid
Pineapple	90 ppm sodium hypochlorite solution	1% calcium chloride
Pomegranate	30 ppm sodium hypochlorite solution	1% calcium chloride

4.3.1. MANGO

4.3.1.1. Physical Parameters

Effect of different packaging materials on physical quality parameters of fresh-cut mango pieces, as judged by sensory scoring (averaged over five days) is shown in Table 15. Fresh-cut mango stored in aluminium & polystyrene tray without KMnO4 sachet recorded superior score.

4.3.1.2. Physiological parameters

Effect of different packaging materials on physiological parameters of fresh-cut mango pieces averaged over five days is shown in Table 16.

4.3.1. 2. 1. Physiological loss in weight (PLW)

Physiological loss in weight was least for the fresh- cut mango pieces packed in poly styrene tray (8.56), which was on par with mango pieces packed in aluminium tray, aluminium tray with $KMnO_4$ sachet, and poly styrene tray with $KMnO_4$. Physiological loss in weight was highest for the unpacked sample (18.32) (Table 16.).

Table 15. Effect of packaging on physical quality parameters of fresh-cut mango

Pre-storage treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
UPE	2.95	3.00	3.45	4.40	3.30	2.95	2.85
UPP	2.10	1.45	4.55	4.00	3.55	3.05	2.80
MPE	5.85	4.40	5.50	7.75	6.20	6.10	5.25
MPP	6.05	4.05	6.80	7.15	7.45	7.85	7.40
Al	11.00	11.55	12.05	11.30	12.05	11.45	11.45
PS	11.75	11.70	11.55	11.45	11.90	11.90	11.65
UPE + S	7.10	8.05	4.95	4.40	4.65	5.90	6.90
UPP+ S	6.80	7.00	4.65	3.75	6.90	5.65	7.85
MPE+ S	7.20	6.40	5.95	5.35	6.70	6.10	5.15
MPP+ S	5.90	7.40	6.40	4.85	3.85	4.90	4.20
Al+ S	10.75	11.50	10.75	11.50	10.75	10.75	11.45
PS+ S	11.40	11.05	11.35	10.70	11.15	11.50	10.95
Control	2.15	3.45	3.05	4.40	2.55	2.90	3.10
Kendalls W[(a)]	0.793	0.881	0.724	0.704	0.813	0.793	0.808
Assymp Syg	0.000	0.000	0.000	0.000	0.000	0.000	0.000

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S – Micro-ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro-ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

Table 16. Effect of packaging on physiological parameters of fresh-cut mango

Treatments	Physiological loss in weight (%)	Percent leakage (%)
Un ventilated polyethylene	12.74	73.53
Unventilated polypropylene	12.71	74.49
Micro ventilated polyethylene	13.99	75.92
Micro ventilated polypropylene	13.83	76.14
Aluminium tray	8.59	70.94
Polystyrene tray	8.56	70.79
Un ventilated polyethylene + $KMnO_4$ sachet	11.76	78.13
Unventilated polypropylene + $KMnO_4$ sachet	12.61	80.03
Micro ventilated polyethylene+ $KMnO_4$ sachet	12.68	76.63
Micro ventilated polypropylene+ $KMnO_4$ sachet	13.59	77.86
Aluminium tray+ $KMnO_4$ sachet	8.67	70.93
Polystyrene tray+ $KMnO_4$ sachet	8.89	73.44
Control	18.32	80.53
CD (P=0.05%)	1.15	3.94

4.3.1. 2. 2. Percent leakage

Percent leakage was least for the sample packed in poly styrene tray (70.79) which was on par with the sample packed in aluminium tray with $KMnO_4$ sachet (70.93), aluminium tray (70.94), poly styrene tray with $KMnO_4$ sachet (73.44), unventilated polyethylene (73.53), and poly propylene (74.49). Percent leakage was highest for the un packed cut mango pieces (80.53), which was on par with all the samples packed in unventilated and micro-ventilated poly ethylene and poly propylene covers with KMnO4 sachet.

4.3.1.3. Chemical parameters

Effect of different packaging materials on chemical quality parameters of fresh- cut mango pieces averaged over five days of storage is shown in Table 17.

4.3.1. 3. 1. Acidity

Acidity was least for the fresh- cut mango pieces packed in aluminium tray (0.53), which was on par with the sample packed in polystyrene tray(0.62). Acidity was highest for the cut mango pieces packed in unventilated PE (1.18) (Table 17).

4.3.1. 3. 2. Total Soluble Solids

TSS was highest for the cut mango pieces packed in polystyrene tray with $KMnO_4$ sachet (8.70), which was on par with the samples packed in aluminium tray with $KMnO_4$ sachet (8.25)and polystyrene tray (8.00) (Table 18). TSS was least for the cut mango pieces packed in micro ventilated polypropylene with $KMnO_4$ sachet (6.33), which was on par with the samples packed in microventilated polyethylene with $KMnO_4$ sachet(6.50), microventilated polypropylene(6.62), unventilated polyethylene with $KMnO_4$ sachet(6.75), unventilated polypropylene (7.00) and polyethylene (7.08)

Table 17. Effect of packaging on chemical quality parameters of fresh-cut mango

Treatments	Chemical quality parameters					
	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit.C (mg/100g)	Carotenoids (mg/100g)	Total phenol (mg/100g)
UPE	1.18	7.08	17.48	33.38	0.003	38.75
UPP	0.75	7.00	16.79	30.92	0.004	37.30
MPE	0.75	7.42	18.45	31.90	0.003	35.92
MPP	0.65	6.62	16.68	32.97	0.004	34.45
Al	0.53	7.50	19.28	35.83	0.006	31.53
PS	0.62	8.00	19.51	34.82	0.016	32.43
UPE + S	0.78	6.75	15.65	28.85	0.004	33.28
UPP+ S	0.82	7.67	17.50	28.60	0.003	32.53
MPE+ S	0.87	6.50	16.01	27.55	0.003	34.80
MPP+ S	0.67	6.33	17.28	29.03	0.004	29.93
Al+ S	0.65	8.25	19.80	35.05	0.007	27.15
PS+ S	0.70	8.70	21.24	34.30	0.008	26.78
Control	0.80	7.42	15.41	28.33	0.002	28.63
CD (P= 0.05%)	0.09	0.79	1.99	2.42	0.0065	2.36

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

4.3.1.3.3. Starch

Starch content was highest for the cut mango pieces packed in polystyrene tray with $KMnO_4$ sachet (21.24), which was on par with the mango pieces packed in aluminium tray with $KMnO_4$ sachet (19.80), polystyrene (19.51) and in aluminium tray (19.28). Starch content was least for the unpacked cut mango pieces(15.41) which was on par with the sample packed in unventilated (15.65) and microventilated (16.01) polyethylene with $KMnO_4$ sachet, microventilated (16.68) and unventilated(16.79) polypropylene and microventilated polypropylene with $KMnO_4$ sachet (17.28) (Table 17).

4.3.1.3.4. Vitamin C

Vitamin C content was highest in the cut mango pieces packed in aluminium tray (35.83) which was on par with the samples packed in aluminium tray with $KMnO_4$ sachet (35.05), polystyrene tray with (34.30) and without (34.82) $KMnO_4$ sachet(Table 17). Vitamin C content was least in the cut mango pieces packed in microventilated polyethylene with $KMnO_4$ sachet (27.55), which was on par with the samples packed in unventilated (28.60) and microventilated (29.03) polypropylene with $KMnO_4$ sachet, unventilated polyethylene with $KMnO_4$ sachet(28.85) and unpacked cut mango pieces(28.33).

4.3.1.3.5. Carotenoids

Cut mango pieces packed in polystyrene tray recorded the highest (0.016) carotenoid content. This was followed by the mango pieces packed in polystyrene tray with $KMnO_4$ sachet (0.008) which was on par all other samples(Table 17).

4.3.1.3.6. Total Phenol

Total phenol content was least in the cut mango pieces packed in polystyrene tray with $KMnO_4$ sachet (26.78), which was on par with the samples packed in aluminium tray with $KMnO_4$ sachet (27.15) and unpacked cut mango pieces (28.63). Total phenol was maximum in mango pieces packed in unventilated polyethylene (38.75) which was on par with those in unventilated polypropylene (37.30) (Table 17).

Based on different physical, chemical and physiological parameters, the following top ranking four packaging materials were selected for further microbial analysis.

1. Aluminium tray
2. Polystyrene tray
3. Aluminium tray+ $KMnO_4$ sachet
4. Polystyrene tray+ $KMnO_4$ sachet

4.3.2. PAPAYA

4.3.2. 1. Physical Parameters

Effect of different packaging materials on physical quality parameters of fresh- cut papaya pieces, as judged by sensory scoring (averaged over five days) is shown in Table 18. Papaya pieces stored in aluminium and polystyrene tray with or without $KMnO_4$ sachet recorded superior scoring in all physical parameters like appearance, colour, flavour, texture and taste along with juiciness and overall acceptability.

4.3.2.2. Physiological parameters

Effect of different packaging materials on physiological parameters of fresh-cut papaya pieces averaged over five days is shown in Table 19.

Table 18. Effect of packaging on physical quality parameters of fresh-cut papaya

Treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
UPE	4.75	3.75	4.17	6.00	4.75	3.00	5.50
UPP	4.0	3.75	3.50	5.33	4.75	9.00	4.50
MPE	5.50	5.75	6.83	6.17	6.75	6.50	5.50
MPP	9.00	8.5	7.33	7.33	9.00	6.50	7.00
Al	11.50	11.25	10.83	11.17	11.00	11.50	11.25
PS	10.5	12.25	11.67	11.33	11.00	11.50	11.25
UPE + S	5.50	4.75	4.00	4.17	6.50	6.50	5.50
UPP+ S	5.50	5.50	6.83	6.17	7.50	6.50	8.50
MPE+ S	3.25	5.5	5.33	4.83	2.75	3.00	3.75
MPP+ S	4.00	2.75	4.17	4.50	2.25	3.00	3.75
Al+ S	12.25	10.00	11.67	11.17	11.50	11.5	11.25
PS+ S	11.25	11.25	11.67	11.83	12.25	11.5	12.25
Control	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kendalls W	0.936	0.879	0.850	0.778	0.959	1.00	0.933
Assymp Syg	0.033	0.000	0.002	0.005	0.000	0.020	0.000

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

Table 19. Effect of packaging on physiological parameters of fresh-cut papaya

Treatments	Physiological loss in weight (%)	Percent leakage (%)
Un ventilated polyethylene	8.98	67.41
Unventilated polypropylene	8.13	68.20
Micro ventilated polyethylene	9.44	67.60
Micro ventilated polypropylene	9.19	63.41
Aluminium tray	5.98	61.84
Polystyrene tray	5.95	65.41
Un ventilated polyethylene + $KMnO_4$ sachet	9.20	68.91
Unventilated polypropylene + $KMnO_4$ sachet	8.58	71.78
Micro ventilated polyethylene+ $KMnO_4$ sachet	9.01	71.83
Micro ventilated polypropylene+ $KMnO_4$ sachet	9.05	68.24
Aluminium tray+ $KMnO_4$ sachet	6.50	64.03
Polystyrene tray+ $KMnO_4$ sachet	6.95	66.92
Control	14.71	71.96
CD (P=0.05%)	0.88	4.96

4.3.2.2.1. Physiological loss in weight (PLW)

Physiological loss in weight was least in fresh- cut papaya pieces packed in poly styrene tray (5.95), which was on par with the samples packed in aluminium tray (5.98) and aluminium tray with KMnO4 sachet (6.50). Physiological loss in weight was highest for the unpacked sample (14.71) (Table 19.).

4.3.2.2.2. Percent leakage

Percentage leakage was lowest in fresh- cut papaya pieces packed in aluminium tray (61.84) which was on par with the samples packed in micro ventilated polypropylene (63.41), aluminium tray with $KMnO_4$ sachet (64.03) and poly styrene tray (65.41). Percent leakage was highest in unpacked cut papaya pieces (71.96).

4.3.2. 3. Chemical parameters

Effect of different packaging materials on chemical quality parameters of fresh- cut papaya pieces is shown in Table 20.

4.3.2. 3. 1. Acidity

Acidity was least for the fresh- cut papaya pieces packed in aluminium and polystyrene tray (0.05) which was on par with samples packed in polystyrene (0.053) and aluminium (0.056) tray with $KMnO_4$ sachet. Acidity was highest for the unpacked sample (0.088) which was on par with the samples packed in unventilated polypropylene (0.082), micro ventilated polyethylene (0.083) and poly propylene (0.080) with $KMnO_4$ sachet (Table 20).

Table 20. Effect of packaging on chemical quality parameters of fresh-cut papaya

Treatments	Chemical quality parameters					
	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit.C (mg/100g)	Carotenoids (mg/100g)	Total phenol (mg/100g)
UPE	0.064	7.03	11.28	38.45	0.026	26.07
UPP	0.082	6.95	11.33	31.24	0.005	24.68
MPE	0.063	7.32	10.85	35.15	0.002	25.82
MPP	0.07	5.58	11.71	35.58	0.003	27.33
Al	0.05	7.92	12.91	38.72	0.04	22.83
PS	0.05	7.45	13.44	43.74	0.004	22.30
UPE + S	0.07	5.92	10.49	31.40	0.003	22.78
UPP+ S	0.069	6.13	10.72	32.53	0.003	22.97
MPE+ S	0.083	6.15	9.42	33.09	0.024	23.92
MPP+ S	0.080	6.58	9.23	32.94	0.005	24.37
Al+ S	0.056	8.58	11.10	39.88	0.039	21.33
PS+ S	0.053	6.92	13.04	38.34	0.045	21.48
Control	0.088	5.87	10.41	31.14	0.013	21.98
CD (P= 0.05%)	0.0102	0.56	1.48	4.08	0.007	1.67

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S- Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

4.3.2.3.2. Total Soluble Solids

Total Soluble Solid was highest for the fresh- cut papaya pieces packed in aluminuim tray with KMnO4 sachet(8.58), followed by the sample packed in aluminuim (7.92) and polystyrene (7.45) tray. TSS was least for the cut papaya pieces packed in micro ventilated poly propylene (5.58) which was on par with the un packed sample (5.87) and samples packed in unventilated polyethylene (5.92) and poly propylene (6.13) with $KMnO_4$ sachet(Table 20).

4.3.2.3.3. Starch

Starch content was highest for the cut papaya pieces packed in polystyrene tray (13.44), which was on par with the samples packed in polystyrene with $KMnO_4$ sachet (13.04), and aluminium tray (12.91). Starch content was lowest in the sample packed in micro ventilated poly propylene with $KMnO_4$ sachet (9.23), which was on par with the samples packed in micro ventilated polyethylene with $KMnO_4$ sachet (9.42), unpacked sample (10.41) and unventilated polyethylene with $KMnO_4$ sachet(10.49) (Table 20).

4.3.2.3.4. Vitamin C

Vitamin C was highest for the cut papaya pieces packed in poly styrene tray(43.74) which was on par with pieces packed in aluminium tray with $KMnO_4$ sachet (39.88). Vitamin C was least for the unpacked papaya pieces (31.14) which was on par with samples packed in unventilated polyethylene(31.24) other unventilated and micro-ventilated polyethylene and polypropylene with $KMnO_4$ sachet(Table 20.).

4.3.2. 3. 5. Carotenoids

Carotenoid content was highest for the cut papaya pieces packed in polystyrene tray with $KMnO_4$ sachet (0.045) which was on par with samples packed in aluminium tray (0.04) and aluminium tray with $KMnO_4$ sachet (0.039). Carotenoid content was least for the cut papaya pieces packed in micro ventilated poly ethylene (0.002) which was on par with the samples packed in micro ventilated (0.003) and unventilated (0.005) polypropylene, unventilated polyethylene (0.003) and polypropylene (0.003) with $KMnO_4$ sachet, polystyrene tray (0.004) and in micro ventilated polypropylene with $KMnO_4$ sachet(0.005).

4.3.2. 3. 6. Total Phenol

Total phenol was lowest in cut papaya pieces packed in Aluminuim tray with $KMnO_4$ sachet (21.33), which was on par with the sample packed in PS tray with $KMnO_4$ sachet, unpacked sample(21.98), sample packed in un ventilated PE with $KMnO_4$ sachet (21.98), and un ventilated PP with $KMnO_4$ sachet(22.97),aluminium (22.83) and in polystyrene (22.30). Total phenol was highest in the cut papaya pieces packed in micro ventilated polypropylene (27.33) (Table 20).

Based on different physical, chemical and physiological parameters, the following top ranking four packaging materials were selected for further microbial analysis.

1. Aluminium tray
2. Polystyrene tray
3. Aluminium tray+ $KMnO_4$ sachet
4. Polystyrene tray+ $KMnO_4$ sachet

4.3.3. PINEAPPLE

4.3.3.1. Physical Parameters

Effect of different packaging materials on physical quality parameters of fresh- cut pineapple pieces, as judged by sensory scoring (averaged over five days) is shown in Table 21. Pineapple pieces stored in aluminium and polystyrene tray with or without $KMnO_4$ sachet recorded superior scoring in all physical parameters like appearance, colour, flavour, texture and taste along with juiciness and overall acceptability.

Table 21. Effect of packaging on physical quality parameters of fresh-cut pineapple

Treatments	Mean sensory scores					
	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
UPE	6.6	3.5	1.5	3.40	3.75	3.00	3.38
UPP	5.5	3.6	4.7	6.10	4.25	5.25	6.50
MPE	8.0	6.0	7.0	6.60	9.13	7.63	6.00
MPP	6.6	7.7	8.2	9.50	7.13	9.00	9.13
Al	10.0	10.4	9.7	10.60	10.63	11.50	11.00
PS	10.4	10.8	9.7	10.60	10.25	10.38	10.25
UPE + S	6.6	7.1	2.8	3.40	4.75	3.25	3.75
UPP+ S	3.0	5.4	5.6	6.40	4.38	4.75	3.63
MPE+ S	6.6	5.0	7.5	6.10	5.75	6.13	6.63
MPP+ S	3.9	8.2	9.3	6.90	6.88	7.75	7.75
Al+ S	11.0	11.1	11.7	10.10	11.25	10.63	10.50
PS+ S	10.4	10.4	10.1	9.80	10.75	10.50	11.50
Control	2.4	1.8	3.2	1.50	2.13	1.25	1.00
Kendalls W	0.685	0.671	0.713	0.624	0.657	0.761	0.788
Assymp Syg	0.00	0.00	0.00	0.00	0.002	0.00	0.00

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene sachet
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

4.3.3.2. Physiological parameters

Effect of different packaging materials on physiological parameters of fresh-cut pineapple pieces averaged over five days is shown in Table 22.

4.3.3.2.1. Physiological loss in weight (PLW)

Physiological loss in weight was least for the fresh- cut pineapple pieces packed in aluminium tray with $KMnO_4$ sachet (2.69), which was on par with the pieces kept in aluminium tray (2.94), PS tray with (3.46) and without (3.77) $KMnO_4$ sachet, and unventilated polypropylene (4.12). Physiological loss in weight was highest for the unpacked sample (Table 22.) .

4.3.3.2.2. Percent leakage

Percent leakage was the least for the cut pineapple pieces packed in aluminium tray (59.09), which was on par with the sample packed in PS tray (60.98). This was followed by the sample packed in aluminium tray with $KMnO_4$ sachet (63.47). Percent leakage was highest for the sample packed in micro ventilated polyethylene with $KMnO_4$ sachet (74.84), which was on par with the sample packed in micro ventilated (72.96) and unventilated (71.36) polypropylene with $KMnO_4$ sachet and unpacked sample(71.22).

4.3.3.3. Chemical parameters

Effect of different packaging materials on chemical quality parameters of fresh- cut pineapple pieces averaged over five days is shown in Table 23.

Table 22. Effect of packaging on physiological parameters of fresh-cut pineapple

Treatments	Physiological loss in weight (%)	Percent leakage (%)
Un ventilated polyethylene	4.49	67.16
Unventilated polypropylene	4.12	64.80
Microventilated polyethylene	4.75	69.01
Microventilated polypropylene	5.21	66.14
Aluminium tray	2.94	59.09
Polystyrene tray	3.77	60.98
Un ventilated polyethylene + KMnO4 sachet	6.07	69.56
Unventilated polypropylene + KMnO4 sachet	4.60	71.36
Microventilated polyethylene+ KMnO4 sachet	5.76	74.84
Microventilated polypropylene+ KMnO4 sachet	4.47	72.96
Aluminium tray+ KMnO4 sachet	2.69	63.47
Polystyrene tray+ KMnO4 sachet	3.46	65.50
Control	11.95	71.22
CD (P=0.05%)	1.49	3.74

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

4.3.3.3.1. Acidity

Acidity was lowest for the fresh- cut pineapple pieces packed in polystyrene tray with $KMnO_4$ sachet (0.084), which was on par with all other pieces except the pieces packed in unventilated polypropylene (0.217) (Table 23).

4.3.3. 3. 2. Total Soluble Solids

TSS was highest for the cut pineapple pieces packed in aluminium tray (15.00), which was on par with the pieces packed in aluminium (14.75) and polystyrene (13.33) tray with $KMnO_4$ sachet. TSS was minimum for the cut pineapple pieces packed in micro ventilated polyethylene (10.50), which was on par with the pineapple pieces packed in all other packages except those in polystyrene trays (Table 23).

4.3.3. 3. 3. Starch

Starch content was highest for the fresh- cut pineapple pieces packed in polystyrene tray (16.19), which was on par with the pieces packed in polystyrene (15.67) and aluminium tray (15.03) with $KMnO_4$ sachet. Starch content was least in cut pineapple pieces packed in micro ventilated polypropylene (11.18), which was on par with the pieces packed in micro ventilated polyethylene (11.43) and polypropylene (11.97) with $KMnO_4$ sachet, unpacked sample(11.87), unventilated polypropylene with (12.02) and without (12.09)$KMnO_4$ sachet and unventilated polyethylene with $KMnO_4$ sachet (12.31) (Table 23).

4.3.3.3.4. Vitamin C

Vitamin C content was highest for the cut pineapple pieces packed in polystyrene tray (39.07), which was on par with the sample packed in Alumunium tray with (38.01)and without (38.82) $KMnO_4$ sachet and polystyrene tray with $KMnO_4$ sachet (37.32). Vitamin C content was lowest and same for the cut pineapple pieces

Table 23. Effect of packaging on chemical quality parameters of fresh-cut pineapple

Treatments	Chemical quality parameters					
	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit. C (mg/100g)	Carotenoid (mg/100g)	Total phenol (mg/100g)
UPE	0.097	10.92	13.27	35.66	0.001	37.80
UPP	0.217	11.08	12.09	35.54	0.001	34.62
MPE	0.104	10.50	13.70	34.13	0.002	36.09
MPP	0.104	11.00	11.18	33.11	0.001	36.03
Al	0.085	15.00	14.02	38.82	0.002	31.77
PS	0.088	13.17	16.19	39.07	0.002	30.58
UPE + S	0.120	10.92	12.31	35.21	0.000	32.70
UPP+ S	0.108	11.08	12.02	35.18	0.001	33.90
MPE+ S	0.106	11.08	11.43	32.86	0.002	34.10
MPP+ S	0.110	11.33	11.97	33.60	0.003	29.60
Al+ S	0.088	14.75	15.03	38.01	0.003	26.93
PS+ S	0.084	13.33	15.67	37.32	0.003	27.10
Control	0.121	11.00	11.87	32.86	0.001	29.55
CD (P=0.05%)	0.095	1.76	1.65	2.76	.0005	2.81

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

packed in micro ventilated polyethylene with $KMnO_4$ sachet and unpacked cut pineapple pieces(32.86). This was on par with all other samples, except those packed in unventilated PE(35.66) (Table 23).

4.3.3. 3. 5. Carotenoids

Fresh- cut pineapple pieces packed in micro ventilated polypropylene, aluminium and polystyrene, all with KMnO4 sachet, recorded the highest carotenoid content(0.003). Pineapple pieces packed in unventilated polypropylene and polyethylene, micro ventilated polypropylene, unventilated polypropylene with KMnO4 sachet and the unpacked pieces recorded the lowest carotenoid content(0.001) (Table 23).

4.3.3. 3. 6. Total Phenol

Total phenol was least in the cut pineapple pieces packed in aluminium tray with $KMnO_4$ sachet(26.93), which was on par with the sample packed in polystyrene tray (27.10) and micro ventilated polypropylene (29.60), both with $KMnO_4$ sachet and unpacked pineapple pieces(29.55). Phenol content was highest in the cut pineapple pieces packed in unventilated polyethylene (37.80), which was on par with the samples packed in micro ventilated polyethylene (36.09) and polypropylene (36.03) (Table 23).

Based on different physical, chemical and physiological parameters, the following top ranking four packaging materials were selected for further microbial analysis.

1. Aluminium tray
2. Polystyrene tray
3. Aluminium tray+ $KMnO_4$ sachet
4. Polystyrene tray+ $KMnO_4$ sachet

4.3.4. POMEGRANATE

4.3.4.1. Physical Parameters

Effect of different packaging materials on physical quality parameters of pomegranate arils, as judged by sensory scoring (averaged over five days) is shown in Table 24. Pomegranate arils stored in aluminium and polystyrene tray with or without $KMnO_4$ sachet recorded superior scoring in all physical parameters like appearance, colour, flavour, texture and taste along with juiciness and overall acceptability.

4.3.4. 2. Physiological parameters

Effect of different packaging materials on physiological parameters of pomegranate arils is shown in Table 25.

4.3.4.2.1. Physiological loss in weight (PLW)

Physiological loss in weight was least for the pomegranate arils packed in Aluminium tray (3.89) which was on par with the arils packed in polystyrene tray (4.65) and aluminium tray (4.96), both with $KMnO_4$ sachet. Physiological loss in weight was highest for the unpacked pomegranate arils (12.85) (Table 25.).

4.3.4.2.2. Percent leakage

Percent leakage was least for the pomegranate arils packed in polystyrene tray with $KMnO_4$ sachet (18.29), which was on par with the arils packed in aluminium tray with (19.19) or without (19.29) $KMnO_4$ sachet, polystyrene tray(19.56), and unventilated polyethylene (20.32). Percent leakage was highest for the unpacked pomegranate arils (26.82), which was on par with the sample packed in micro ventilated polyethylene with

Table 24. .Effect of packaging on physical quality parameters of pomegranate arils

Treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
UPE	4.00	3.17	4.67	2.63	2.50	2.13	3.38
UPP	5.33	5.17	5.00	3.00	3.25	3.25	4.25
MPE	5.33	7.0	8.67	5.88	5.50	7.00	5.50
MPP	7.17	5.17	4.17	5.75	5.00	7.63	6.13
Al	10.5	9.17	11.33	10.13	10.88	10.75	11.13
PS	9.67	9.83	11.33	11.38	11.50	10.88	11.00
UPE + S	6.33	5.17	4.17	5.25	4.13	5.00	4.38
UPP+ S	5.00	8.00	5.83	8.38	6.88	4.50	8.13
MPE+ S	7.17	7.50	7.33	6.50	6.88	7.75	5.88
MPP+ S	8.67	7.33	5.50	7.75	8.38	6.00	7.75
Al+ S	9.83	11.17	10.5	12.25	11.50	11.25	11.75
PS+ S	10.50	11.33	10.5	10.13	11.50	11.75	10.00
Control	1.50	1.00	2.00	2.00	3.13	3.13	1.75
Kendalls W (a)	0.706	0.684	0.687	0.775	0.086	0.789	0.736
Assymp Syg	0.013	0.017	0.016	0.000	0.000	0.000	0.000

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sac

Table 25. Effect of packaging on physiological parameters of pomegranate arils

Packaging materials	Physiological loss in weight (%)	Percent leakage (%)
Un ventilated polyethylene	5.47	20.32
Unventilated polypropylene	5.59	22.22
Microventilated polyethylene	5.61	23.02
Microventilated polypropylene	5.99	25.30
Aluminium tray	3.89	19.29
Polystyrene tray	5.18	19.56
Un ventilated polyethylene + $KMnO_4$ sachet	7.45	23.75
Unventilated polypropylene + $KMnO_4$ sachet	7.38	25.67
Microventilated polyethylene+ $KMnO_4$ sachet	7.30	25.88
Microventilated polypropylene+ $KMnO_4$ sachet	7.87	25.65
Aluminium tray+ $KMnO_4$ sachet	4.96	19.19
Polystyrene tray+ $KMnO_4$ sachet	4.65	18.29
Control	12.85	26.82
CD (P=0.05%)	1.12	2.19

$KMnO_4$ sachet(25.88), unventilated polypropylene with $KMnO_4$ sachet(25.67), micro ventilated polypropylene with (25.65) or without (25.30) $KMnO_4$ sachet(Table 25.).

.4.3.4. 3. Chemical parameters

Effect of different packaging materials on chemical quality parameters of pomegranate arils is shown in Table 26.

4.3.4. 3. 1. Acidity

Acidity was lowest for the pomegranate arils packed in aluminium tray with $KMnO_4$ sachet (0.043), which was on par with the samples packed in polystyrene tray with or without $KMnO_4$ sachet, aluminium tray (0.044), unventilated PE (0.050), micro ventilated polyethylene or polypropylene (0.050) and unventilated PP with KMnO4 sachet (0.051). Acidity was highest for the arils packed in micro ventilated polyethylene with $KMnO_4$ sachet (0.066), which was on par with the unpacked sample (0.059), samples packed in unventilated polyethylene with $KMnO_4$ sachet (0.059), unventilated polypropylene (0.059) and micro ventilated polypropylene with $KMnO_4$ sachet(0.058) (Table 26).

4.3.4. 3. 2. Total Soluble Solids

TSS was highest for the sample packed in micro ventilated polyethylene (15.57), which was on par with all samples except the sample packed in unventilated polypropylene (14.65) (Table 26).

4.3.4. 3. 3. Starch

Starch content was highest for the pomegranate aril packed in aluminium tray with $KMnO_4$ sachet (18.83), which was on par with the aril packed in polystyrene tray with (18.70) or without (18.54) $KMnO_4$ sachet and unventilated polyethylene(18.04). Starch content was lowest for the unpacked aril (15.21), which was on par with the arils

Table 26. Effect of packaging material on chemical quality parameters of pomegranate arils

Treatments	Chemical quality parameters					
	Acidity (%)	TSS (^{0}B)	Starch (%)	Vit.C (mg/100g)	Carotenoids (mg/100g)	Total phenol (mg/100g)
UPE	0.050	14.92	18.04	46.36	0.030	219.50
UPP	0.059	14.65	16.87	45.22	0.005	203.50
MPE	0.050	15.57	15.98	48.65	0.005	232.83
MPP	0.050	15.33	17.19	45.19	0.005	225.33
Al	0.044	15.47	16.62	48.09	0.044	185.33
PS	0.044	15.43	18.54	47.90	0.008	187.50
UPE + S	0.059	14.95	16.07	42.33	0.003	205.03
UPP+ S	0.051	14.83	15.60	42.59	0.003	190.30
MPE+ S	0.066	15.40	16.62	43.29	0.024	217.00
MPP+ S	0.058	15.35	15.82	38.89	0.005	181.17
Al+ S	0.043	15.27	18.83	44.33	0.038	187.33
PS+ S	0.044	15.20	18.70	43.30	0.045	181.83
Control	0.059	15.43	15.21	28.97	0.012	195.50
CD (P= 0.05%)	0.0138	0.76	1.48	2.43	0.0071	16.56

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

packed in unventilated (16.07) or micro ventilated (16.62) polyethylene with $KMnO_4$ sachet, unventilated (15.60) or micro ventilated (15.82) polypropylene with $KMnO_4$ sachet, micro ventilated polyethylene (15.98) unventilated polyethylene(16.87) and those arils packed in aluminium tray(16.62) (Table 26).

4.3.4. 3. 4. Vitamin C

Vitamin C content was highest for the pomegranate arils packed in microventilated PE (48.65), which was on par with the arils packed in aluminium (48.09), polystyrene (47.90) tray and unventilated polyethylene(46.36). Vitamin C content was lowest in the unpacked pomegranate arils (28.97) (Table 26).

4.3.4. 3. 5. Carotenoids

Carotenoid content was highest for the pomegranate arils packed in polystyrene tray with $KMnO_4$ sachet (0.045), which was on par with the arils packed in aluminium tray(0.044) and aluminium tray with $KMnO_4$ sachet (0.038). Carotenoid content was lowest for the arils packed in unventilated polyethylene or polypropylene with $KMnO_4$ sachet (0.003), which was on par with the sample packed in unventilated polypropylene(0.005), micro ventilated polyethylene (0.005) or PP (0.005) microventilated polypropylene with $KMnO_4$ sachet(0.005) and polystyrene tray (0.008) (Table 26).

4.3.4. 3. 6. Total Phenol

Total phenol content lowest for the pomegranate arils packed in micro ventilated polypropylene with $KMnO_4$ sachet (181.17), which was on par with the samples packed in PS tray with (181.83) without (187.50) $KMnO_4$ sachet, aluminium tray with (187.33) and without (185.33), $KMnO_4$ sachet, unventilated PP with $KMnO_4$ sachet (190.30) and unpacked sample(195.50). Total phenol content was highest for the sample packed in miroventilated polyethylene (232.83), which was on par with the samples packed in microventilated polypropylene (225.33), unventilated polyethylene (219.50), and microventilated polyethylene with $KMnO_4$ sachet (217.00) (Table 26).

Based on different physical, chemical and physiological parameters, the following top ranking four packaging materials were selected for further microbial analysis.

1. Aluminium tray
2. Polystyrene tray
3. Aluminium tray+ $KMnO_4$ sachet
4. Polystyrene tray+ $KMnO_4$ sachet

4.3.5. FRESH- CUT FRUIT MIX

4.3.5. 1. Physical Parameters

Effect of different packaging materials on physical quality parameters of fresh- cut fruit mix, as judged by sensory scoring (averaged over five days) is shown in Table 27. Fruit mix, stored in aluminium and polystyrene tray with or without $KMnO_4$ sachet recorded superior scoring in all physical parameters like appearance, colour, flavour, texture and taste along with juiciness and total freshness. Fruit mix kept in Un ventilated polyethylene as well as polypropylene covers scored least for all sensory parameters, along with unpacked fruit mix.

4.3.6. ENUMERATION OF TOTAL MICROBIAL LOAD AND ELECTION OF BEST PACKAGING MATERIAL

Both bacterial and fungal population were similar in cut mango or pineapple pieces and pomegranate arils kept in all the packaging materials (Table 28.)Bacterial load was least (4.83) for the papaya pieces packed in polystyrene tray without $KMnO_4$

Table 27. Effect of packaging on physical quality parameters of fresh-cut fruit mix

Treatments	Appearance	Colour	Flavour	Texture	Taste	Juiciness	Overall acceptability
UPE	4.17	3.83	2.17	4.17	5.00	3.17	3.17
UPP	4.67	6.17	4.33	4.67	5.50	4.00	3.67
MPE	7.50	6.83	6.67	6.67	6.17	6.17	6.50
MPP	7.33	7.50	5.87	6.83	5.00	6.67	5.83
Al	8.83	9.00	10.67	9.50	10.50	11.00	11.33
PS	9.17	9.00	11.50	11.67	9.83	11.00	11.33
UPE + S	6.83	6.83	5.67	5.33	5.50	6.17	5.83
UPP+ S	7.50	5.00	9.00	4.50	6.33	7.00	6.83
MPE+ S	8.33	8.00	8.33	8.17	7.17	6.67	8.83
MPP+ S	8.33	6.83	6.67	5.50	6.33	5.33	5.83
Al+ S	9.83	9.00	9.33	9.50	10.50	11.00	9.17
PS+ S	9.17	9.00	9.83	11.67	9.83	11.00	10.67
Control	1.33	1.00	1.00	2.83	3.33	1.83	2.00
Kendalls W(a)	0.498	0.684	0.743	0.672	0.519	0.746	0.719
Assymp Syg	0.033	0.000	0.002	0.005	0.000	0.020	0.000

UPE - Un ventilated polyethylene
UPP - Unventilated polypropylene
MPE - Micro ventilated polyethylene
MPP -Micro ventilated polypropylene
Al -Aluminium tray
PS - Polystyrene tray

UPE + S - Un ventilated polyethylene + $KMnO_4$ sachet
UPP + S - Unventilated polypropylene+ $KMnO_4$ sachet
MPE+ S - Micro ventilated polyethylene+ $KMnO_4$ sachet
MPP+ S - Micro ventilated polypropylene+ $KMnO_4$ sachet
Al + S - Aluminium tray+ $KMnO_4$ sachet
PS+ S - Polystyrene tray + $KMnO_4$ sachet

Table 28. Microbial count on treated fresh-cut fruits kept in selected packaging materials

Packaging materials	Bacteria (cfu/g x 10^3)	Fungi (cfu/g x 10^3)
MANGO		
Aluminium tray	6.50(2.55)	0.667(1.025)
Polystyrene tray	7.00(2.59)	1.00(1.13)
Aluminium tray+ $KMnO_4$ sachet	6.83(2.49)	1.00(1.088)
Polystyrene tray+ $KMnO_4$ sachet	7.33(2.85)	1.167(1.257)
CD (P=0.05%)	NS	NS
PAPAYA		
Aluminium tray	7.00 (2.68)	0.67(1.03)
Polystyrene tray	4.83(2.25)	0.50 (0.90)
Aluminium tray+ $KMnO_4$ sachet	6.67(2.59)	2.17(1.53)
Polystyrene tray+ $KMnO_4$ sachet	8.50(2.90)	1.00 (1.13)
CD (P=0.05%)	0.379	0.479
PINEAPPLE		
Aluminium tray	7.833(2.83)	0.667(1.03)
Polystyrene tray	7.833(2.82)	0.167(0.79)
Aluminium tray+ $KMnO_4$ sachet	5.833(2.49)	0.833(1.07)
Polystyrene tray+ $KMnO_4$ sachet	7.833(2.85)	0.667(1.02)
CD (P=0.05%)	NS	NS
POMEGRANATE		
Aluminium tray	5.50 (2.35)	0.50 (0.94)
Polystyrene tray	6.833 (2.59)	0.667 (0.99)
Aluminium tray+ $KMnO_4$ sachet	7.500 (2.75)	0.333 (0.88)
Polystyrene tray+ $KMnO_4$ sachet	5.667 (2.39)	0.667 (1.03)
CD (P=0.05%)	NS	NS

Values in parenthesis show square root transformed values sachet which was on par with the papaya pieces packed with aluminium tray with $KMnO_4$ sachet. Bacterial load was highest (8.50) for the sample packed in polystyrene tray with $KMnO_4$ sachet. Fungal count was least (0.50) for the papaya pieces packed in polystyrene tray which was on par with samples packed in aluminium tray **(**0.67) and polystyrene tray with $KMnO_4$ sachet (1.00).

As the microbial population was similar in all the packaging materials, most economic packaging material, aluminium container without ethylene absorbent was selected for fresh-cut pineapple, mango and pomegranate arils. In case of papaya, polystyrene tray can also be considered as the best packaging material, considering the comparative efficiency in reducing the microbial population.

Combining all the steps like sanitization, pre- treatment and packaging, the best protocol was standardized for each fresh- cut fruit and fruit mix.

Fruits	Standardized protocol		
	Sanitization solution	Pre-treatment	Packaging and storage
Mango	60 ppm sodium hypochlorite	0.1% KMS and 0.1% citric acid	Packaging in aluminium tray covered with cling film and refrigerated storage
Papaya	90 ppm sodium hypochlorite	0.1% KMS and 0.1% citric acid	
Pineapple	90 ppm sodium hypochlorite	1% Calcium Chloride	
pomegranate	30 ppm sodium hypochlorite	1% Calcium Chloride	

4.4. QUALITY PARAMETERS AND ACCEPTABILITY OF THE STANDARDIZED PROTOCOL

4.4.1. Quality parameters

Physical quality parameters like colour and texture of the fresh- cut fruits prepared using standardized protocol were analyzed.

4.4.1.1. Colour

Colour parameters viz., total colour change/ total colour difference (TCD) and yellowness index (YI) of fresh- cut fruits, prepared using the standardized protocol, were recorded continuously for 5 days (0^{th} to 4^{th} day) (Table 29).

4.4.1.1.1. Yellowness index

Yellowness index of the fresh-cut mango pieces at the time of storage was 121.07. It gradually increased to 126.71 on the 2^{nd} day and then decreased to 114.67 on the 4^{th} day of storage. In papaya, yellowness index was 92.02 on the day of preparation. It was increased to 94.71 on the 2^{nd} day and to 94.65 on the 4^{th} day of storage. In pine apple, yellowness index was 73.87 on the day of preparation increased to 75.09 on the 1^{st} day and to 76.00on the 4^{th} day of storage. Yellowness index was 47.04 for pomegranate at the time of storage. There was a gradual increase of YI and it was 54.32 on the 4^{th} day of storage.

4.4.1.1.2. Total colour change (difference)

Total colour change of the treated fruit pieces increased gradually from the day of treatment. In mango, colour change from the day of storage to 1^{st} day of storage was 5.98 and the colour change increased gradually and the colour change from 0^{th} day to 4^{th} day was 18.06. In papaya, colour change from the day of storage to 1^{st} day of storage was 4.44 and the colour change from 0^{th} day to 4^{th} day was 13.06. In pineapple, colour change from the day of storage to 1^{st} day of storage was 4.07 and the colour change from 0^{th} day to 4^{th} day was 9.60. Colour change of pomegranate from 0^{th} day to 1^{st} day was 3.91 and the colour change from 0^{th} to 4^{th} day was 12.29.

Table 29. Colour of fresh-cut fruits prepared by standardized protocol during storage.

YELLOWNESS INDEX				
Day	**Mango**	**Papaya**	**Pineapple**	**pomegranate**
0	121.07	92.02	73.87	47.04
1	121.65	91.21	75.09	48.24
2	126.71	94.71	74.97	48.90
3	119.05	92.32	75.36	53.76
4	114.67	94.65	76.00	54.32
TOTAL COLOUR CHANGE				
Day 0 to Day 1	5.98	4.44	4.07	3.91
Day 0 to Day 2	14.38	5.43	5.84	9.61
Day 0 to Day 3	16.21	6.40	8.68	10.08
Day 0 to Day 4	18.06	13.06	9.60	12.29

4.4.1.2. Textural quality

Textural quality parameters viz., firmness, springiness, cohesiveness and chewiness of fresh- cut fruits, prepared using the standardized protocol, were recorded continuously for 5 days (0^{th} to 4^{th} day) (Table 30).

Hardness (firmness)

Firmness of the fresh- cut fruit pieces and arils prepared using the standardized protocol, showed a gradual decrease during storage. In mango, firmness on the day of preparation was 15.20 N, which was decreased to 7.11 by the end of storage. In papaya, firmness decreased from 110.78 N at the time of preparation to 53.65 on the 4^{th} day of storage. In pineapple firmness was 47.24 N at the time of preparation and it was decreased to 38.46 N, 5 days after storage. In pomegranate, firmness decreased from 96.47 to 83.39N.

Springiness

Springiness of the fresh- cut fruit pieces prepared using the standardized protocol, showed a gradual decrease during storage. In mango, springiness was highest on the day of its preparation (0.08) and was decreased to 0.04 on 4^{th} day of storage. In papaya springiness was decreased from 0.07 to 0.06, in pineapple, it was decreased from 0.10 to0.09 and in pomegranate arils there was no change in springiness (0.05) during storage.

Cohesiveness

Cohesiveness of the fresh- cut fruit pieces and arils prepared using the standardized protocol, showed a gradual increase during storage. In mango, cohesiveness was 0.09 and it increased to 0.13 on the 4^{th} day of storage. In papaya, cohesiveness was 0.14 on the day of preparation and it increased to 0.16 on 4^{th} day after storage. In pineapple, there was no change in cohesiveness during its storage and in

Table 30. Textural changes of fresh-cut fruits prepared by standardized protocol during storage.

Day from storage	HARDNESS (FIRMNESS) (N)			
	Mango	Papaya	Pineapple	Pomegranate
0	15.20	110.78	47.24	96.47
1	12.67	58.27	44.89	92.08
2	8.14	55.56	41.80	91.93
3	7.60	53.70	40.40	87.65
4	7.11	53.65	38.46	83.39
Day from storage	SPRINGINESS			
0	0.08	0.07	0.10	0.05
1	0.07	0.07	0.10	0.05
2	0.06	0.07	0.10	0.05
3	0.06	0.07	0.09	0.05
4	0.04	0.06	0.09	0.05
Day from storage	COHESIVENESS			
0	0.09	0.14	0.12	0.16
1	0.10	0.15	0.12	0.17
2	0.12	0.15	0.12	0.19
3	0.12	0.15	0.12	0.21
4	0.13	0.16	0.12	0.22
Day from storage	CHEWINESS			
0	0.11	1.10	0.56	0.81
1	0.10	0.70	0.52	0.82
2	0.07	0.50	0.51	0.83
3	0.06	0.47	0.44	0.97
4	0.06	0.45	0.34	0.96

pomegranate, it was increased from 0.16 on the day of preparation to 0.22 on 4th day of storage.

Chewiness

Chewiness of the fresh- cut fruit pieces prepared using the standardized protocol, showed a gradual decrease during storage, except in pomegranate. In mango, chewiness was 0.11 on the day of preparation and it was decreased to 0.06 on the 4th day of storage. In papaya, chewiness was decreased from 1.10 on the day of preparation to 0.34 on the 4th day of storage. In pomegranate chewiness was slightly increased from 0.81 to 0.96.

4.5. COST OF PRODUCTION

Cost of production of 100 gram fresh- cut fruit and fruit mix, prepared using the standardized protocol was computed as per the current market rate (Table 31.). Cost of production of 1Kg. fresh- cut mango fruits considering the labour and overhead cost involved was Rs.97/-, Rs. 52.60/ - for papaya, Rs. 83.76/- for pineapple and cost of production was Rs. 262.66/- for 1 kg. pomegranate arils. Cost of production of 1Kg. fresh- cut fruit mix was calculated as Rs. 124/-

4. 6. ACCEPTABILITY OF STANDARDIZED TECHNOLOGY

Acceptability of the prepared products, analysed by sensory evaluation by a 10 member semi trained panel is shown in Table 32.

Table 31. Cost of production

Particulars	Mango			Papaya			Pineapple			Pomegranate		
	Rate(Rs)	Qnty required	Price (Rs)	Rate	Qnty required	Price	Rate	Qnty required	Price	Rate	Qnty required	Price
Purchasing of fruits	50/kg	1.5kg	75	20/kg	1.5kg	30	30/kg	2kg	60	160/kg	2kg	240
Sodi.hypochlorite (4%)solution	234/litre	4.5ml	1	234/litre	6.75ml	1.6	6.75ml	6.75ml	1.6	234/litre	2.25kg	50ps
KMS(0.1%)	23/50gm	1gm	50ps	23/50gm	1gm/litre	50ps	-	-	-	-	-	-
Citric acid(0.1%)	244/500gm	1gm	50ps	244/500gm	1gm/litre	50ps	-	-	-	-	-	-
Cal.Chloride(1%)	108/500gm	10gm	-	-	-	-	108/500gm	10gm	2.16		10gm	2.16
Aluminium tray	4/tray	4	16		16	16			16			16
Cling film	65/30m roll	1m	2		2	2			2			2
Miscellaneous	-	-	2		2	2			2			2
Total	-	-	97			52.6			83.76			262.66

For fruit mix; total cost of production is average of the cost of production of the four fruits above i.e; Rs.124

Table 32. Mean sensory score for the fresh-cut fruits and fruit mix prepared by standardized protocol.

Fruits	Mean rank based on sensory scoring				
	Days after storage				
	0	1	2	3	4
Mango	8.95	8.85	8.65	8.35	7.95
Papaya	9.0	8.95	8.8	8.55	8.05
Pineapple	9.0	8.95	8.8	8.6	8.25
Pomegranate	9.0	8.95	8.9	8.8	8.5
Fruit-mix	9.0	8.95	8.85	8.7	8.4

Discussion

5. DISCUSSION

The consumer demand for high quality foods requiring only minimum amount of effort and time for preparation has led to the introduction of ready-to-use, convenience foods preserved by mild methods (so-called minimal processing methods) only. However fresh cut products are highly perishable and subjected to fast degradation of quality. Type of handling, temperature, humidity, use of modified atmosphere etc. can influence the microclimate there by influencing the safety and quality of the fresh cut produce. By establishing an efficient and economic protocol for development of fresh cut produce, consumers will be able to buy fresh fruits, which are in ready to use form. This type of convenient food will also increase the dietary consumption of fruits in the present day busy life schedule.

The results of the investigation on “Protocol development for fresh-cut fruits and fruit mix preparation” were analyzed statistically and are discussed in this chapter in four headings.

5. Evaluation of different sanitizing agents
6. Evaluation of different pre-storage treatments
7. Development of packaging and storage systems
8. Quality parameters and acceptability of standardized protocol

5. 1. EVALUATION OF DIFFERENT SANITIZING AGENTS

The fruits intended for peeling and cutting must be easily washable, peelable, and with proper maturity and quality. It is essential to use either a raw material free of contamination, or to clean/decontaminate the produce. Fruits, which are covered with soil, mud or sand, should be carefully cleaned before processing. Surface sanitization of selected fruits was undertaken with sanitizing solutions of different concentrations to ensure microbial safety.

Surface sanitization with sodium hypochlorite at the highest concentration of 120 ppm resulted in least number of bacterial population in mango, papaya and pineapple. But 120 ppm was on par with 90ppm and 60ppm solutions in mango. In papaya and pineapple, 120ppm sodium hypochlorite was on par with 90ppm solution. In Pomegranate, sanitization with all concentrations of sodium hypochlorite solution was equally effective. This may be due to the thick and smooth nature of the outer covering, hindering the action of sanitizer on it. Chlorine compounds are usually used at levels of 50-200 ppm free chlorine and with typical contact times of less than 5 min (Francis and O'Beirne, 2002). Reduction in microbial population was noticed in cabbage too after sanitization with 200 ppm sodium hypochlorite for 10 minute (Fantuzzi and Pushmann 2004). Sodium hypochlorite (NaOCl) is the source of chlorine commonly used in small-scale operations. It is generally used in concentrations of 5.25 percent or 12.75 percent active ingredient in liquid form; because the solid forms readily absorb water from air and release chlorine gas. Surface sanitization with 30 ppm sodium hypochlorite was found to be most effective treatment for preserving visual quality, reducing microbial contamination and enhancing shelf life of cut vegetables (Varghese,2006).

Untreated pineapple and papaya had highest bacterial population. In pineapple this was on par with sanitization using 40^0C water. In mango fruits also, sanitization using 40^0C water had highest number of bacterial population. This is in conformity with the results of Li et al., (2002), who had observed that there was no significant reduction in microbial population following hot water treatments.

For selection of any treatment, efficiency and economics are the two factors to be considered. If lower concentrations are equally effective as highest concentration, use of higher concentration can be avoided considering the safety and economics. Hence based on the efficiency of sanitizers in reducing the bacterial load on the fruit surface, the following lowest concentrations of sanitizers were selected for further study. In mango, 60 ppm sodium hypochlorite solution was selected; 90 ppm solution was selected for papaya and pineapple. As all the concentrations are equally effective, 30 ppm sodium hypochlorite solution was selected as best sanitizing agent for pomegranate.

Several studies have demonstrated that the application of sodium hypochlorite can reduce populations of total aerobic bacteria, yeasts and moulds on the surface of tomato, sweet pepper, cucumber and strawberry (Alvaro et al., 2009; Kim et al., 2010). Sodium hypochlorite (NaOCl), which is the most widely used disinfectant in the food industry fulfills many requirements as the ideal disinfectant. The effectiveness of sodium hypochlorite in the cleaning and disinfection processes depends on the concentration of available chlorine and the pH of the solution. Hypochlorous acid (HOCl) is a weak acid and dissociates to hypochlorite ion (-OCl) and proton (H+) depending on the solution pH. It is generally believed that HOCl is the active species in the germicidal action, whereas the concentration of -OCl is a key factor determining the cleaning efficiency (Fukuzaki, 2006).

The initial microbial load mainly determines product shelf life. To ensure highest microbial safety, the use of low contaminated raw material is a prerequisite for subsequent reduction of microbial load during processing.

5.2. EVALUATION OF DIFFERENT PRE-STORAGE TREATMENTS

Cut surface treatments involving dipping fruit pieces into aqueous solutions containing antimicrobial agents, antioxidants, calcium salts or functional ingredients such as minerals and vitamins are widely practiced to improve quality of fresh-cut fruit. In present study, after surface sanitization, fruits were peeled, made in to small pieces and treated with different pre-storage chemicals viz., preservatives, firming agents, acidulants etc. The effect of different treatments on physiological, physical and chemical quality parameters of fresh cut frits are discussed here.

Minimal processing generally increases the rates of metabolic processes that cause deterioration of fresh products. The physical damage or wounding caused by preparation increases respiration and ethylene production within minutes, and associated increases occur in rates of other biochemical reactions responsible for changes in color (including browning), flavor, texture, and nutritional quality (such as vitamin loss).

Plant tissues are in equilibrium with atmosphere at the same temperature with an RH of 99%-99.5%in the whole fruit, water in the intercellular spaces are not directly exposed to atmosphere. Cutting/peeling a fruit exposes the interior tissues and drastically increases the evaporation rate.

Accelerated weight loss is another major problem with fresh cut fruits. Excess water loss and increased respiration due to physical damage is the main reason for physiological loss in weight. Preparatory processes of fruits such peeling and cutting along with storage temperature may also affect the weight loss. Any reduction in water vapour in the atmosphere below that in the tissues result in faster water loss there by resulting in weight loss (Gaffeny et al., 1985). In the present study also marked reduction in physiological loss in weight was observed in fresh cut fruits.

5.2.1. Mango

Physiological loss in weight was same for all the treated cut mango pieces and the treated mango pieces were having low physiological loss in weight compared to untreated fresh cut mango pieces (Fig.1). Though PLW and percent leakage are highest, osmotic potential was least for the untreated fresh cut mango pieces. They were having the same osmotic potential as that of cut pieces treated with calcium chloride, calcium ascorbate, sodium acid sulphate or KMS and citric acid (Fig.2).

Least osmotic potential is favourable for any fresh cut fruit, as it indicates highest water potential, thereby maintaining turgidity of the fruit cells and freshness of fruit pieces. Calcium chloride treated cut mango pieces had least percentage leakage too making it firm in texture. Least percent leakage is due to high membrane integrity,

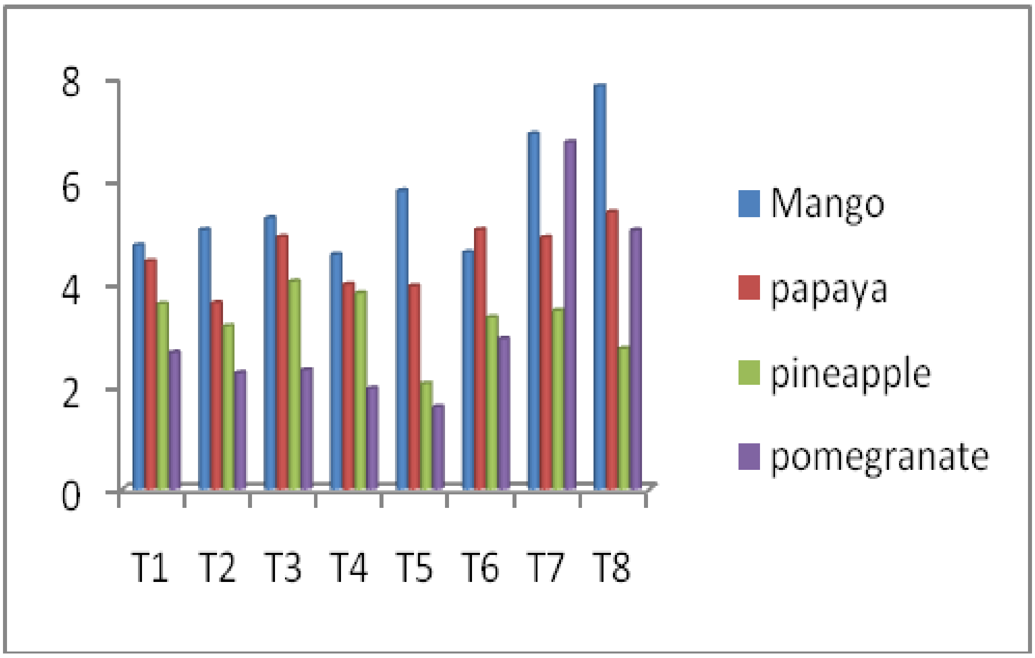


Fig 1. Effect of pre treatments on PLW

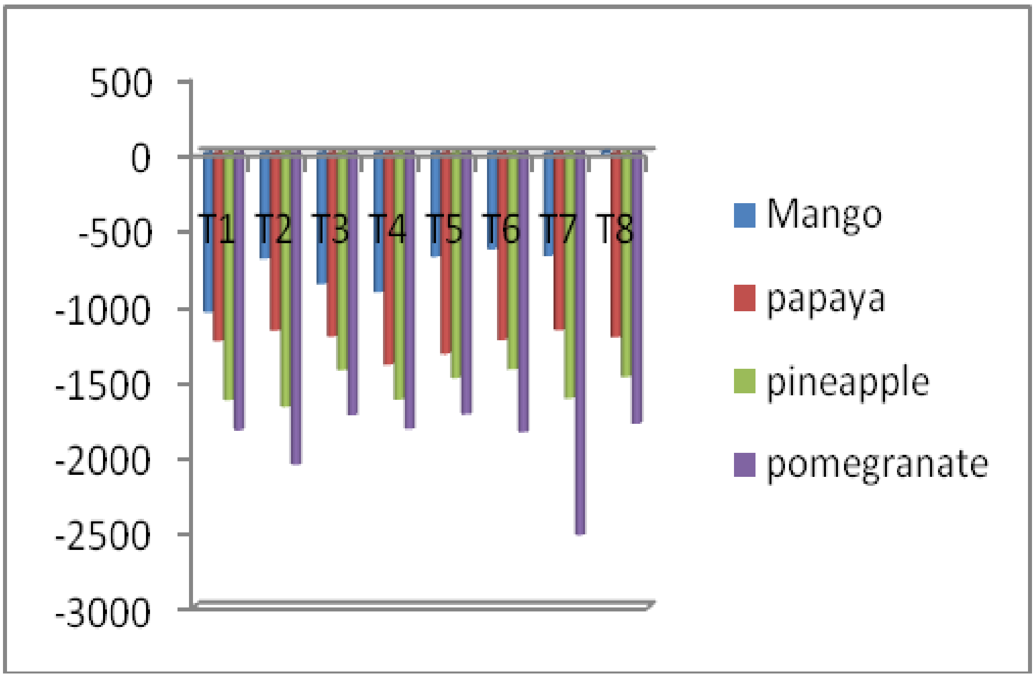


Fig 2. Effect of pre treatments on osmotic potential

which is again a good character for fresh cut fruits. Forms of calcium used in the food industry are calcium lactate, calcium chloride, calcium phosphate, calcium propionate and calcium gluconate, which are used more when the objective is the preservation and/or the enhancement of the product firmness (Alzamora et al., 2005; Luna-Guzman and Barrett, 2000; Manganaris et al.2005). Calcium chloride treated fruit pieces had obtained maximum score for appearance and texture in sensory scoring also supporting the physiological parameters.

Cut mango pieces treated with KMS+ascorbic acid had highest osmotic potential and percentage leakage. As both these are negative parameters for fresh cut fruits, this treatment can be considered inferior as a preservative for mango pieces. Mango fruits heated with this chemical had low score of in physical analysis too. Dong et al., (2000) also reported that sliced pears had a soft texture with juice leakage, when dipped in 1.0% ascorbic acid and 1.0% calcium lactate.

Almost all the chemical parameters tested were influenced by application of pre storage treatments on fresh cut fruits. Fresh cut mango pieces treated with 0.1% KMS+ citric acid exhibited least acidity and highest TSS content. Increased TSS content will be suppressing the acid content there by recording highest score for overall acceptability during sensory analysis. Calcium ascorbate treated fruits had highest TSS, vitamin C, carotenoid content and high starch and they had high organoleptic score for sensory parameters like appearance, flavour, texture and taste also.

Mango pieces treated with sodium acid sulphate had least TSS and highest carotenoid content. As the phenol content was minimum, Sodium Acid Sulphate treated mango pieces scored maximum for colour. But it had least score for texture, taste and juiciness. Fresh cut mango pieces treated with 0.1% KMS+ ascorbic acid had highest phenol there by exhibiting low score for colour during physical analysis. Though untreated fresh cut mango pieces recorded least starch and vitamin C content, it had maximum total soluble solids and minimum phenol content(Fig.6).

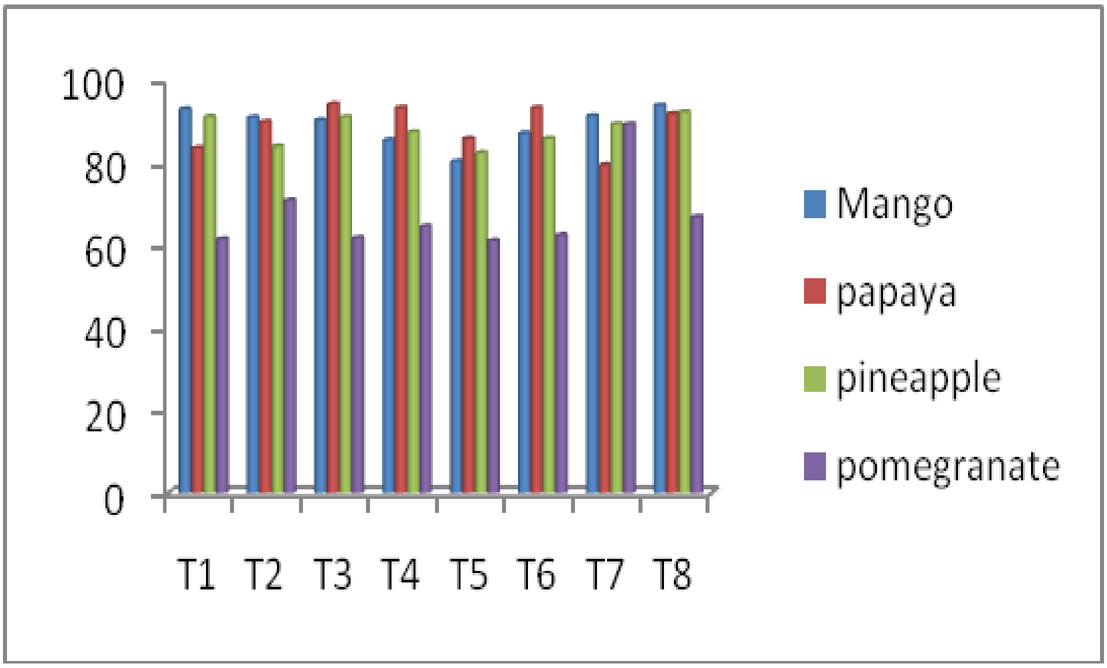


Fig 3. Effect of pre treatments on percent leakage

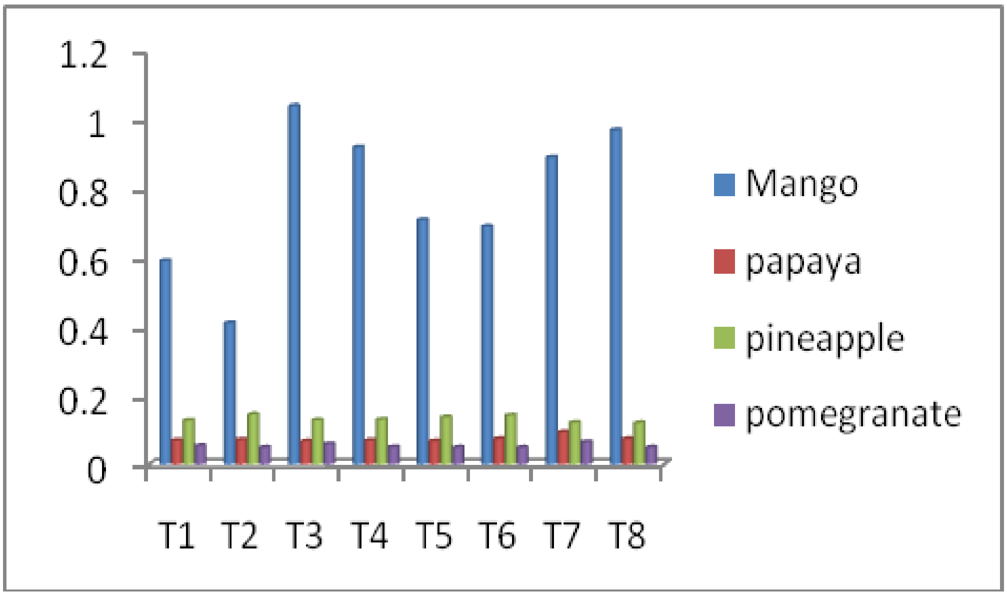


Fig 4. Effect of pretreatments on acidity

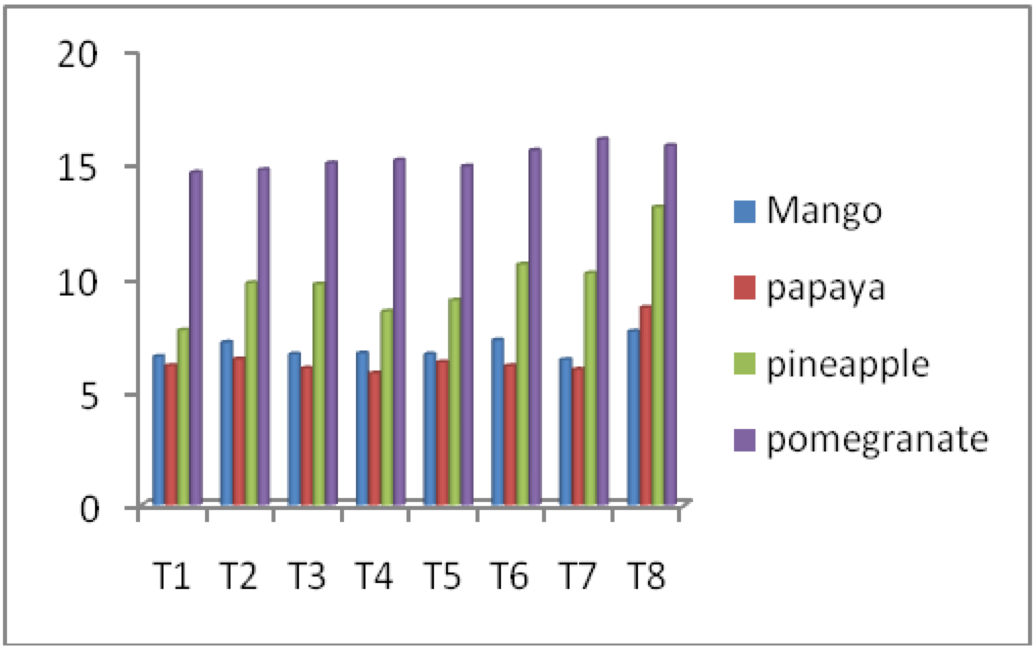


Fig 5. Effect of pretreatments on TSS

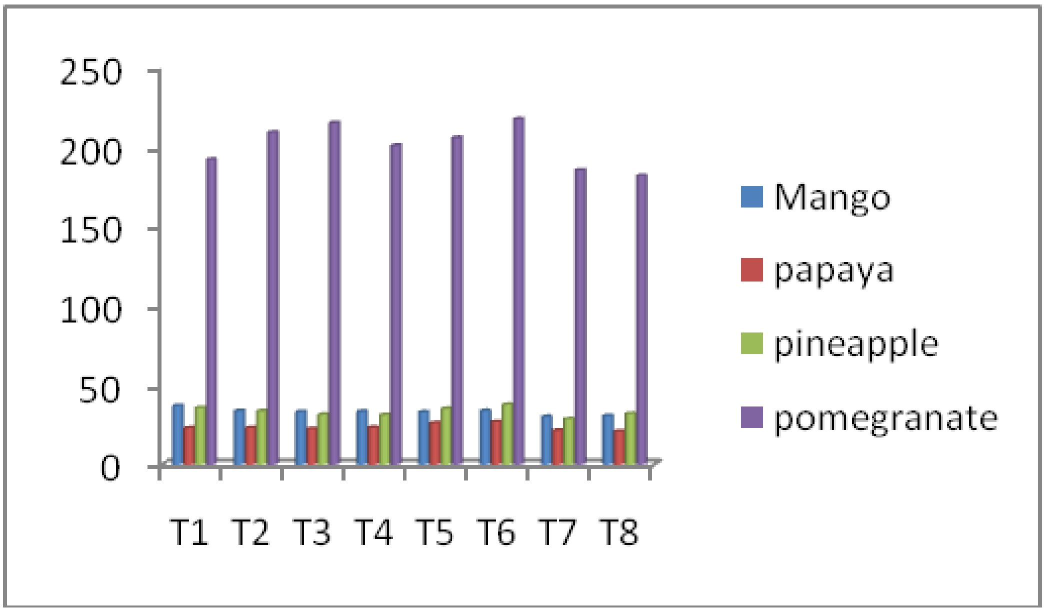


Fig 6. Effect of pretreatments on phenol

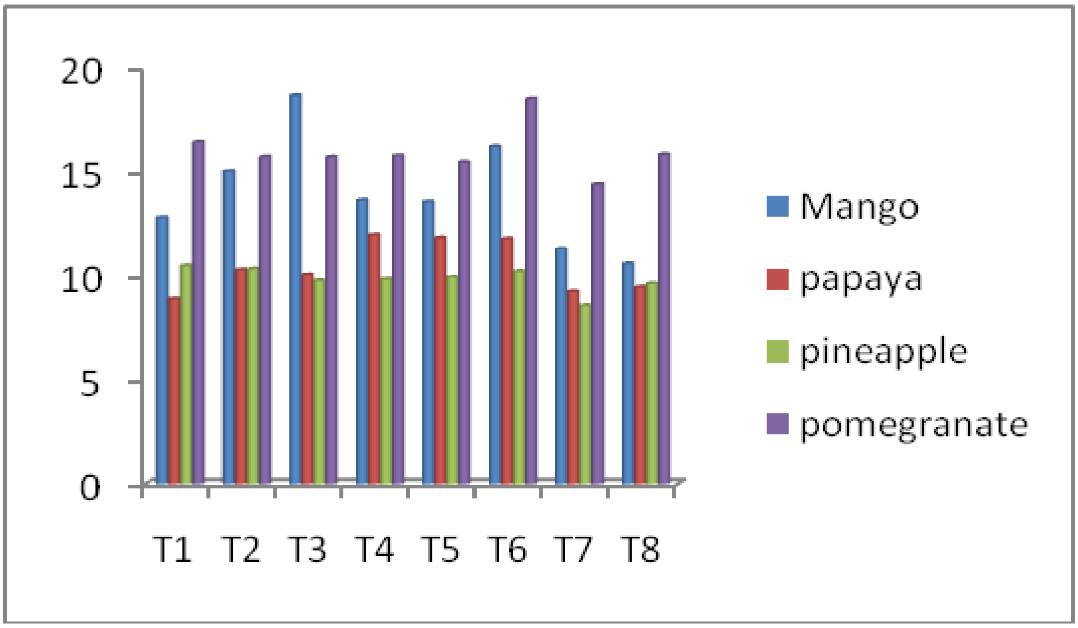


Fig 7. Effect of pretreatments on starch

5.2.2. Papaya

Cut papaya pieces treated with 0.1% KMS + 0.1% citric acid had least physiological loss in weight and percent leakage, hence recording highest score for appearance in sensory scoring. Papaya pieces treated with 0.1% KMS + 0.1% ascorbic acid also had least percent leakage. In experiments conducted by Varghese (2006) also, KMS in combination with citric acid had proved to be the most effective in several vegetables for prolonging shelf life under ambient conditions.

Treatment with 3% sodium acid sulphate also could lower the physiological loss in weight and percent leakage in fresh cut papaya fruits. But the papaya fruits treated with this chemical had highest acidity and lowest Total Soluble Solids, hence obtained very low scores for appearance, flavour, taste and juiciness. Vitamin C content was also lowest for those papaya pieces. Hence the chemical sodium acid sulphate was not considered in papaya for further study.

Starch content was least in cut papaya treated with 0.1% KMS + 0.1% ascorbic acid. As the starch content is less, it will naturally enhance the Total Soluble Solids content. Here also TSS was high in cut papaya treated with KMS and ascorbic acid.

Total Soluble Solids were highest for untreated cut papaya pieces. When cut fruits are dipped in chemical solutions, diffusion of solutes might have taken place there by reducing the TSS content of treated fruits. Tian et al., (1997) had reported a decrease in glucose and fructose content in broccoli stems, when dipped in 47 °C for 7.5 minutes.

Untreated papaya pieces had least vitamin C content. Vitamin C content of cut fruit pieces could be improved by treating with chemicals containing vitamin C, viz., calcium ascorbate or 0.1% KMS + 0.1% ascorbic acid. Other chemical treatments

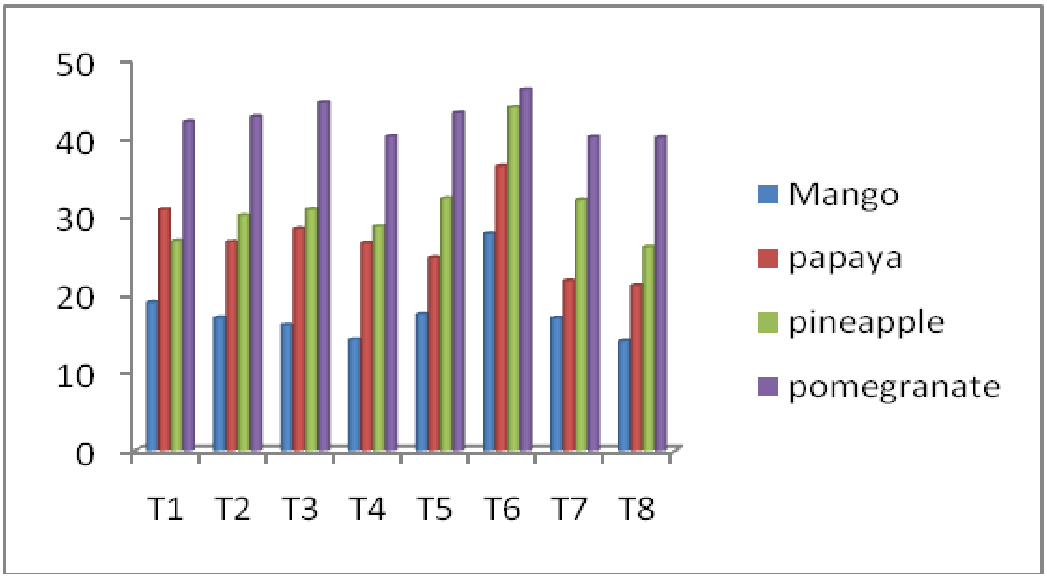


Fig 8. Effect of pretreatments on Vitamin C

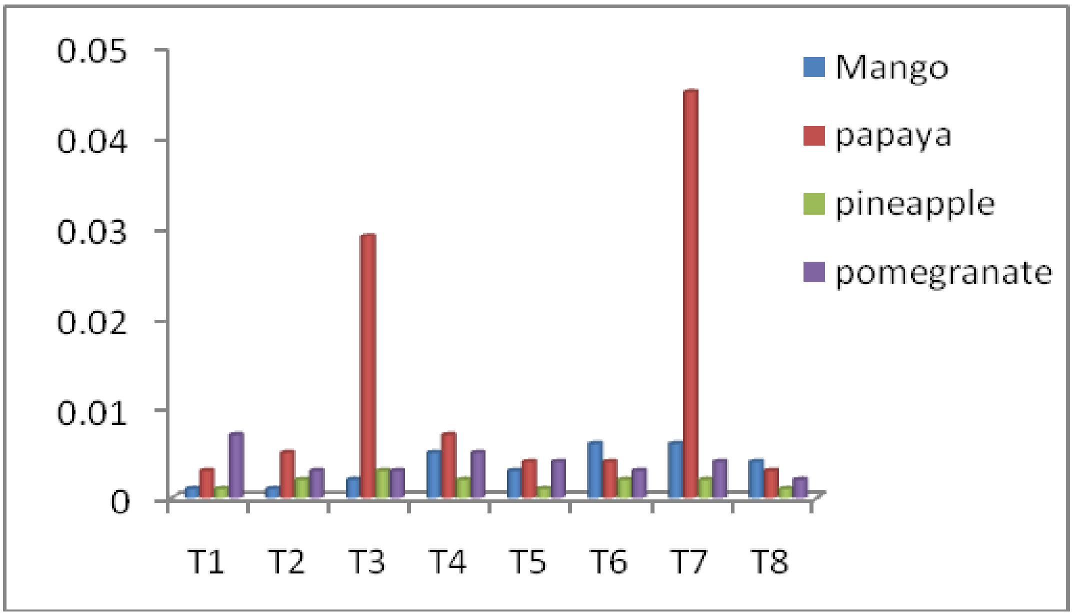


Fig 9. Effect of pretreatments on carotenoid content

reduced the vitamin C content of all fresh cut papaya fruits. The vitamin C content of sliced, cut or bruised fruits and vegetables may diminish rapidly depending upon the handling, processing and storage conditions used. Vitamin C is soluble in water and sensitive to alkali, oxygen, copper, iron and heat. The enzyme ascorbic acid oxidase released from cut cells, will oxidise ascorbic acid to de hydro ascorbic acid which can undergo further degradation to produce products that no longer has any vitamin C activity.

5.2.3. Pineapple

As in other cut fruit samples, pre storage treatments had influenced the physical, physiological and chemical parameters of cut pineapple fruits also. Physiological loss in weight and percent leakage were minimum for calcium chloride treated cut pineapple pieces, thereby giving firmness to the sample. Chardonnet et al., (2003) reported calcium chloride as a widely used preservative and firming agent in the fruits and vegetables industry for fresh-cut commodities.

Luna-Guzman and Barrett (2000) found that application of calcium chloride to cantaloupe melons makes the fruit firmer; the higher the concentration of calcium chloride used, the firmer the fruit.

Percent leakage was least for cut pineapple pieces treated with 0.1% KMS and 0.1% citric acid and calcium ascorbate. Fruit pieces treated with these two chemicals showed superior performance in physical analysis too. Pineapple pieces treated with 0.1% KMS + 0.1% citric acid had obtained highest score for appearance and overall acceptability, whereas those treated with 1% calcium ascorbate had highest score for taste and juiciness. Potassium metabisulphite or sodium benzoate in combination with ascorbic acid was found to retain visual quality, enhance shelf life and reduce microbial load during storage in fresh cut pineapple (Sheela, 2007).

Untreated cut pineapple pieces had the highest total soluble solids and they were least acidic compared to treated pineapple pieces. Pineapple pieces treated with 1% calcium ascorbate had the highest vitamin C and high total soluble solids.

Total phenol was least for fresh cut pineapple pieces treated with 3% sodium acid sulphate. Fan et al (2009) identified sodium acid sulphate as an effective anti browning agent inhibiting microbial growth in apple slices. They had found SAS as the most effective chemical in inhibiting browning and microbial growth in apple slices. In the present study sodium acid sulphate treated fruit pieces had highest score for colour and flavour in evaluation of physical parameters.

Pomegranate

Physiological loss in weight, osmotic potential and percent leakage were least for the pomegranate arils treated with 1% calcium chloride. These three physiological parameters influence the quality of any fresh cut fruit. Pomegranate arils treated with calcium chloride were firm and succulent, exhibiting overall acceptability and juiciness in physical analysis too. Calcium chloride dips have improved firmness of fresh-cut cantaloupe during storage at 5°C(Luna-Guzmán and Barrett, 2000).

Any fresh cut fruit should have low acidity and high total soluble solids for better palatability. Similarly it should have low phenol content to avoid enzymatic browning. Visual quality loss is the main factor limiting the shelf life of fresh cut produce. Browning was not a serious problem in any of the fruit pieces studied, though the phenol content was high in pomegranate arils. Any processed product, whether whole or fresh cut should retain the nutritional quality even after processing. But, as none of the pre- treatments tried showed superior performance for all the quality parameters evaluated, the four pre-treatments having top weighted average ranks were selected for each fruit, for further microbial analysis.

When pre treatments were selected based on weighted average rank, calcium chloride and calcium ascorbate were found superior for all the fruits. Calcium treatments can maintain or improve tissue firmness and crispness of fresh cut fruits. Calcium chloride has been one of the most frequently used salts of calcium and other calcium salts such as calcium lactate, calcium propionate or calcium ascorbate have been investigated as alternative sources of calcium (Dong et al., 2000, Alandes et al., 2006 and Quiles et al., 2007). As calcium ascorbate is very costly, the chemical was not considered for selection.

Combination of preservative and acidulant as a pre storage treatment also had superior performance in maintaining the freshness and quality of cut fruits. Pre storage treatment with 0.1% KMS and 0.1% citric acid was superior for mango, papaya and pineapple, where as 0.1% KMS and 0.1% ascorbic acid was suited for papaya and pomegranate arils. 0.1% sodium benzoate and 0.1% ascorbic acid was effective for fresh cut mango and pineapple pieces, whereas 0.1% sodium benzoate and 0.1% citric acid was effective for pomegranate arils.

As the cut fruits were stored under ambient conditions for evaluating the efficiency of pre storage treatments, they were completely spoilt by the second day of storage itself.

5.2.4. ENUMERATION OF TOTAL MICROBIAL LOAD

Microbial contamination is another major concern in fresh cut fruit industry (Fain, 1996). The growth of microorganisms in fresh cut product is facilitated by plant cell injury, senescence or any stress. Cells injured during minimal processing release fluid containing compounds, which are favourable for microbial growth. With minimal processing, the increase in cut or damaged surface and availability of cell nutrients provide a condition that increase the number and type of microbes that develop. Furthermore, increased handling of the product provides greater opportunity for contamination by pathogenic organisms (Varghese,2006). In the present study when fruit pieces treated with selected chemicals were subjected to microbial analysis, all the selected pre-storage chemicals exhibited almost similar efficiency in microbial control.

Most efficient pre-treatment having capacity to maintain the physical, physiological and chemical quality parameters and to reduce the microbial population of fresh cut fruit pieces, stored under ambient condition, was selected as the efficient pre-storage treatment for each fresh cut fruit piece. Accordingly 0.1% KMS and 0.1% citric acid was selected as the best pretreatment for fresh cut mango and papaya pieces, where as 1% calcium chloride was selected for cut pineapple pieces and pomegranate arils. Several studies have clearly stated the superiority of these two treatments.

Treatment combination of several chemicals was more effective than those applied individually. Sulphur dioxide in potassium metabisulphite has preserving action against bacteria and moulds and inhibit enzymes. It acts as an antioxidant; is a bleaching agent and is reported to be more effective when used along with acidulants like citric acid or ascorbic acid, rather than used alone (Varghese, 2006). In the present study, it was used only in combination. Similar result was obtained by Wang and Buta (2000). The antimicrobial action of organic acids is due to pH reduction, disruption of membrane transport and permeability, anion accumulation as well as reduction in internal cellular pH.

Calcium helps to maintain the fruit cell wall integrity by interacting with pectin to form calcium pectate. Calcium is reported to maintain firmness by cross-linking with cell wall and middle lamella pectin. Santerre et al. (1988) reported that application of citric acid can prevent browning of sliced apple there by providing extended shelf life.

Wide variations observed in the physiological and chemical parameters of the fruits evaluated in the present study make it clear that knowledge of cell structure changes that occur as a result of processing will allow for improvement of shelf life and quality of minimally processed fruits or vegetables in order to maintain “fresh-like characteristics." Quantification of the degree of cellular disruption will allow for the comparison and optimization of preservation processes (Galindo et al.,2005).

5.3. EVALUATION OF PACKAGING SYSTEMS

The minimally processed products must have a fresh appearance, visually acceptable, be of consistent quality throughout storage period in the package, and be reasonably free of defects. Packaging materials have significant effect in reducing microbial population of fresh cut products (Varghese, 2006). Packaged cut materials are subjected to many stresses including deterioration reactions of wounded or senescing tissues, decay caused by growth of micro organisms, water loss from the tissue, increase in respiration and ethylene production. These injuries induce severe damage and stress, with considerable reduction in shelf life of commodity.

Temperature management is important for fresh cut produce industry (Alzamora et al., 2005). Storage at 10^0 C or above is clearly unacceptable because most bacterial foodborne pathogens would grow rapidly on fresh cut products, and even toxin production by *Clostridium botulinum* in some products is possible because of rapid oxygen consumption in the package. Product storage should be at low temperature, preferably 2-4°C, for produce not vulnerable to chilling injury. Storage under low temperature was suggested by Varghese (2006) for restriction of deterioration in minimally processed products under Kerala condition. Hence in the present study, evaluation of packaging system was done under refrigerated condition only with a temperature of 2-4 °C.

When different packaging materials were compared, all the cut fruit samples and pomegranate arils kept in aluminium tray with or without $KMnO_4$ sachet and polystyrene tray had lowest physiological loss in weight and percent leakage, indicating their superiority. Fresh cut fruits packed in these had superior scoring in all physical parameters like appearance, colour, flavour, texture and taste along with juiciness and overall acceptability too. $KMnO_4$ removes ethylene from the system. Removal of ethylene from the storage environment of minimally processed fruits and vegetables can retard tissue softening (Abe and Watada, 1991).

Unventillated or microventillated packages, with or without an ethylene absorbent, were not always good in maintaining physiological quality parameters of fresh cut fruits. Microperforated films having high gas transmission rates for oxygen and carbon dioxide can be used to extend shelf life of highly respiring produce. All unpacked fruit pieces had highest physiological loss in weight (Rai and Paul, 2007). The fresh cut fruits are highly respiring in nature; hence the films selected should have high gas transmission rates for oxygen and carbon dioxide.

Packaging in aluminium and polystyrene trays covered with cling film without keeping any ethylene absorbent had resulted in reduced acidity in all fresh cut fruit. Addition of $KMnO_4$, an ethylene absorbent, in aluminium and polystyrene trays could reduce acidity of fresh cut papaya, pineapple pieces and pomegranate arils.

Packaging in aluminium or polystyrene trays covered with cling film with or without keeping any $KMnO_4$ could maintain the quality parameters such as increased TSS, reduced phenol of all four fresh cut fruits. Retention of nutritional quality parameters like increased carotenoid, starch and vitamin C was noticed in fruits packed in these containers.

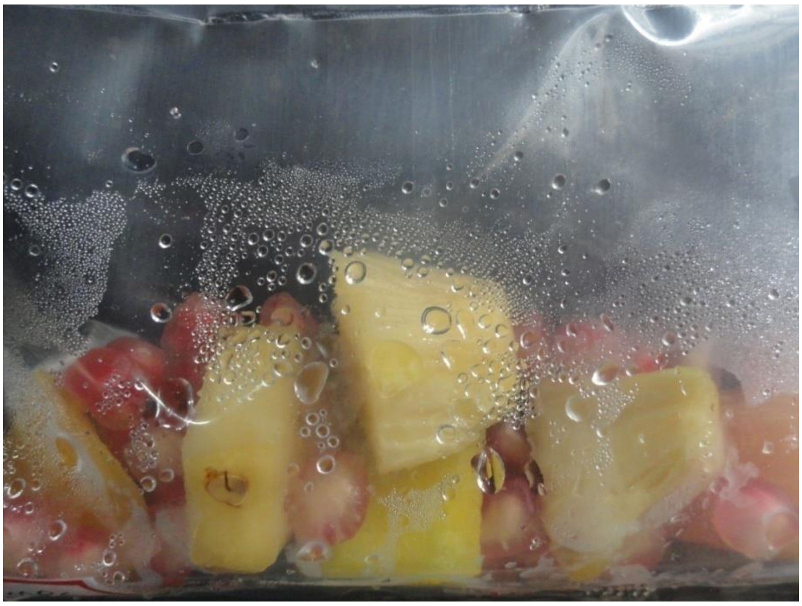
In the present study, unventilated or microventillated polyethylene or polypropylene with or without $KMnO_4$ sachet were found inferior to aluminium or polystyrene trays as it reduced the nutrient content of all fresh cut fruits and fruit mix studied. But in the experiment conducted by Varghese (2006), packaging minimally processed vegetables in unventillated polypropylene and storage under low temperature was found beneficial. The difference in result may be due to the difference in raw material used.

Considering all physical, chemical and physiological parameters, the top ranking four packaging materials viz., aluminium tray and polystyrene tray with or without $KMnO_4$ sachet were selected for further microbial analysis. Packaging of vegetables in polystyrene trays and wrapping with cling film was also recommended by Varghese (2006) for enhanced visual and keeping quality. Semi rigid plastic packaging and packaging in aluminium tray, both covered with cling film, are popular packaging materials for cut fruits, when presented as catering or snack trays. A view of the produce is also made possible in such materials.

When microbial population was analyzed, both bacterial and fungal population were similar in fresh-cut mango, pineapple pieces and pomegranate arils kept in all the packaging materials. But Varghese (2006) could see a reduction in microbial population when cut vegetables are packed in polystyrene tray with cling film. Microbial count was significantly low under refrigerated condition. The influence of low temperature in inhibiting microbial growth on fresh cut products has been reported by Bacts and Tamplin (2002)

When the cut fruits were stored in these trays, wounded fruit tissue respires at a faster rate and accumulation of water droplets takes place inside the packaging containers (Plate 10.). In addition, water molecules from the storage atmosphere sorbs into the cling film, permeant water molecule diffuse through the film and these molecules desorbs from the packaging polymer into the inside of the package, thereby accumulating inside the package (Dash, 2011). This water has to go out of the packages depending on the water vapour permeability characteristics of the packaging film. Addition of ethylene absorbent in the experiment could not make any added advantage on the microbial control. Increased water droplets favors spoilage of fresh-cut produce. It can be concluded that inclusion of a desiccant in the package, for water absorption would have been better than addition of an ethylene absorbent.

Plate 11. Condensation of water vapour inside the packaging



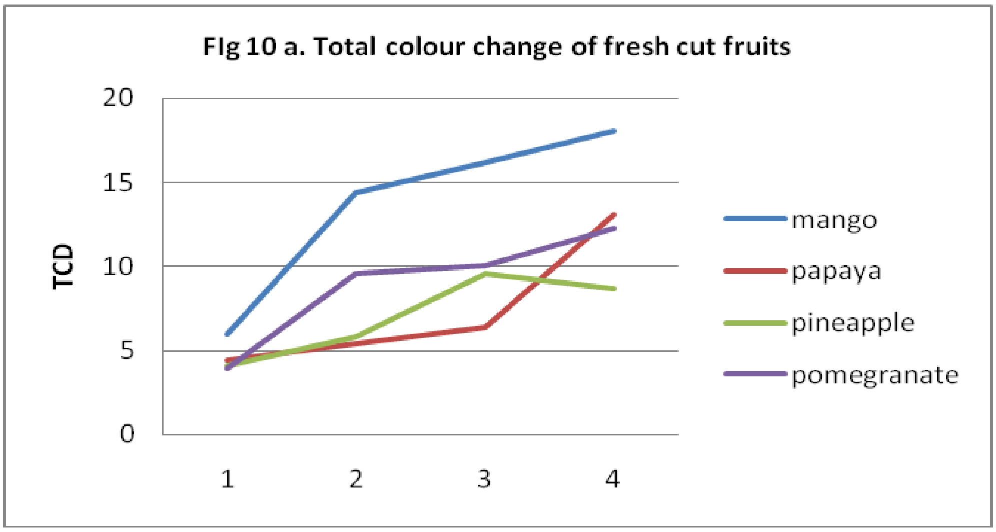
5.3. QUALITY PAAMETERS AND ACCEPTABILITY OF THE STANDARDIZED PROTOCOL

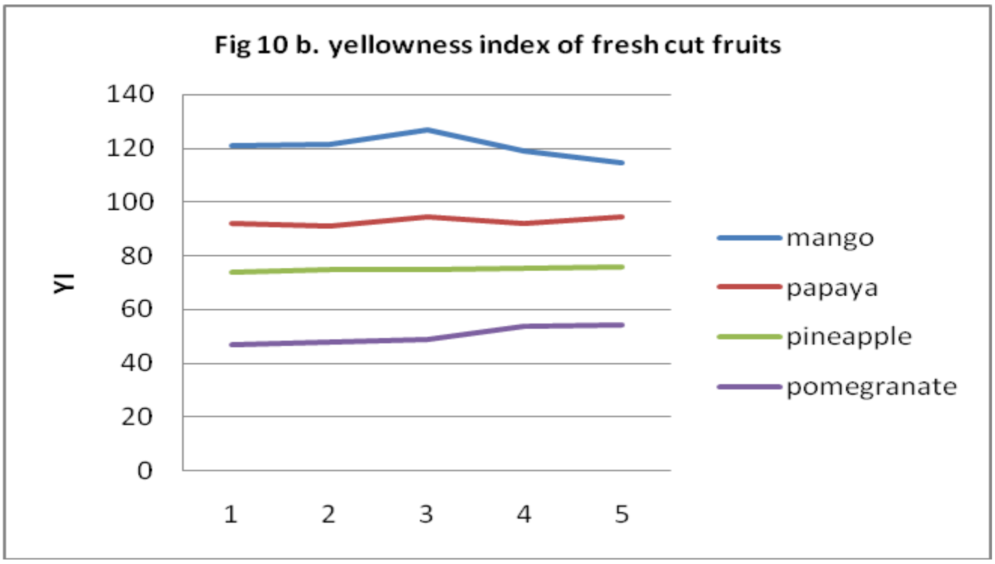
The quality of any food product could be defined by different ways from a widely manner to a more detailed one. One of the most usual meanings is defining the quality as “in conformity with consumer’s requirements and acceptance is determined by their sensory attributes (Aumatell, 2009).

Colour is a primary consumer perceived characteristic of a food and plays an important role. Furthermore, colour of a processed product is often expected to be as similar as possible to the raw one (Mac Dougall, 2002). This is especially important in the case of fresh cut fruits. Texture is another important food quality attribute, defined as a “sensory and functional manifestation of structural, mechanical and surface properties of food, detected through the senses of vision, hearing, touch and kinesthetic” (Szczesniac, 2002). Color and texture are among the key quality attributes for fresh cut fruits also. Any treatment done in the preparation of fresh cut produce or packaging and storage atmosphere can affect food texture. Hence in the present study, colour and textural properties of the prepared fresh cut fruits were analysed by instrumental methods.

Total colour change was increased from the day of preparation to 4th day of storage (Fig 10.a). But the yellowness index showed an initial increase and later it was decreased. Still there was no sharp increase or decrease in the case of yellowness index (Fig 10 b). Carotenoids, being the main group of colouring substances in nature, are responsible for many of the red, orange and yellow colours of fruits. The stability of carotenoids during processing and storage is crucial for product attractiveness and acceptability. Carotenoid degradation affects not only fruit colour, but also nutritive value and flavour. The common degradation pathways are isomerisation, oxidation and fragmentation of the carotenoid molecules, promoted by heat, light and acids (Cinar, 2004). Pigment degradation can be related to physical colour measurements.

Fig 10. Colour changes of fresh cut fruits during 5 days of storage



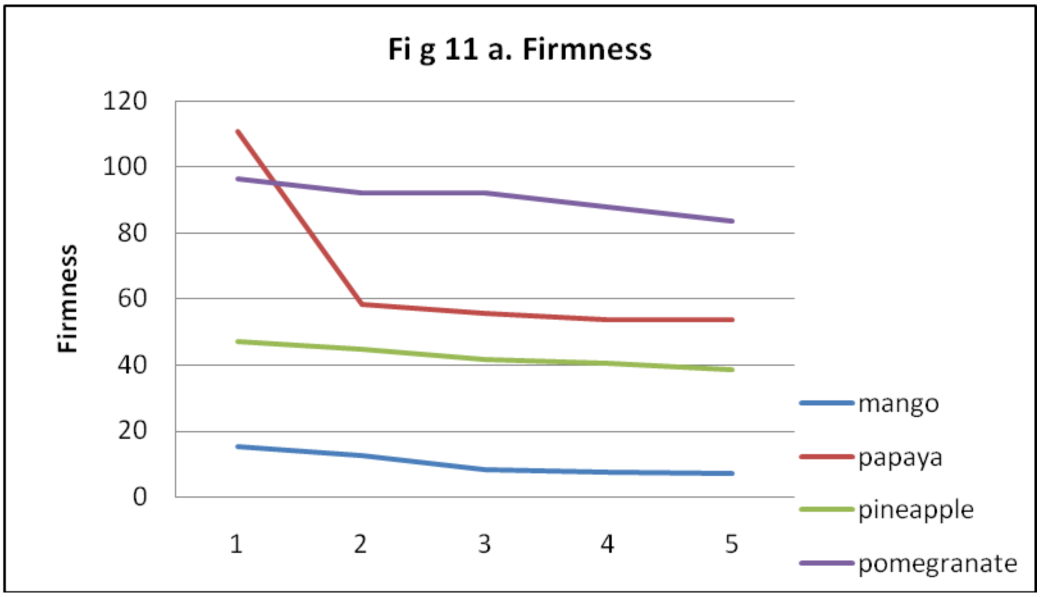


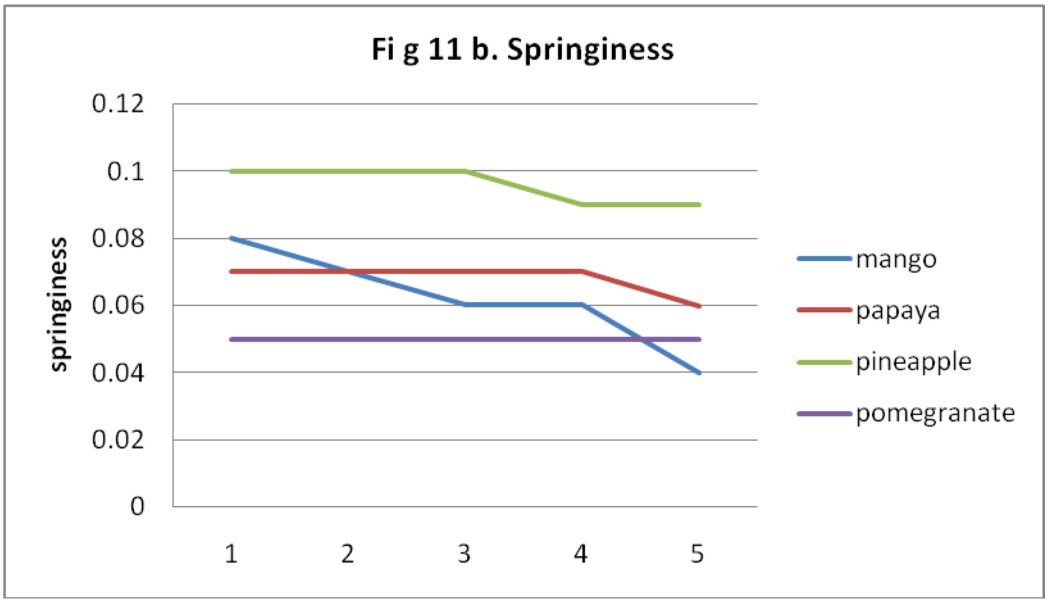
Different textural quality parameters like firmness, springiness, and chewiness were evaluated for assessing the quality of fresh-cut fruits. In these parameters, firmness, springiness, and chewiness of fresh cut fruits, showed a gradual decrease during storage where as cohesiveness showed a gradual increase from 0^{th} to 4^{th} day of storage (Fig 11a-11d). The preparation impact may cause disruption of cell membranes, allowing diffusion of water and low-weight molecules, resulting in turgor loss. However, the most significant softening occurs subsequently as a result of an increase in pectic substances solubilisation, loss of turgor pressure, and some degree of cell separation (Galindo et al, 2005; Smout et al., 2005).

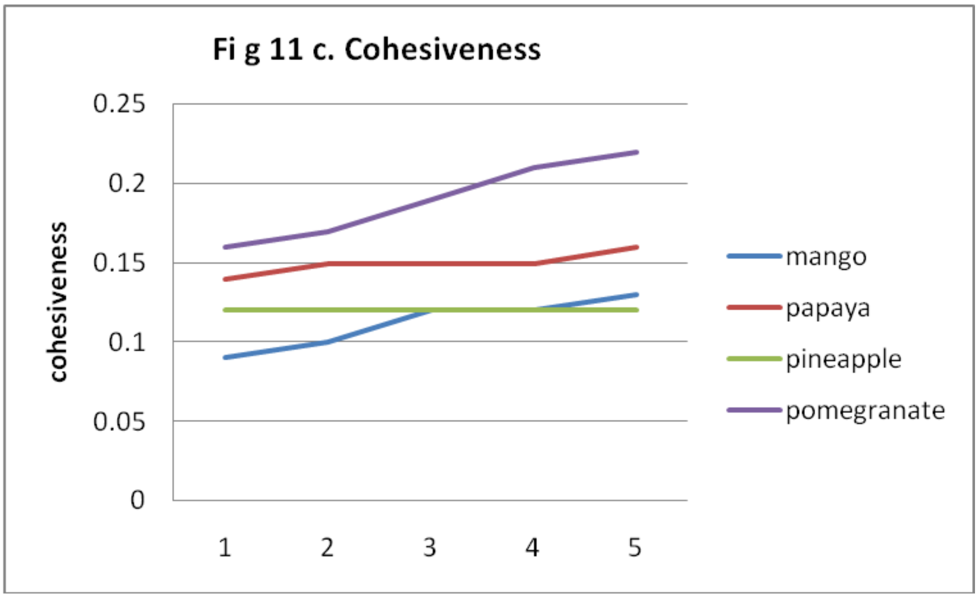
Hardness showed a drastic reduction where as springiness and chewiness showed a slight reduction only. Cohesiveness showed a small increase from the initial value. There were exceptions; in pomegranate, chewiness was increased slightly from the initial value and in pineapple, there was no change in cohesiveness. Springiness, cohesiveness and chewiness are the factors deciding mastigatory effect. The major textural parameters viz., hardness or firmness showed a reduction. In mango and papaya, firmness became half by the end of fifth day, where as in pineapple and pomegranate the reduction was less only. Increased firmness in papaya is due to the hard texture of papaya fruit near the fruit rind.

Though the texture showed gradual changes, fresh cut fruits and fruit mix prepared as per the standardised protocol were acceptable to the sensory panel even by the end of 5^{th} day (Fig 12.). The fresh cut samples were not having any visual symptom of microbial attack too. All the fresh cut fruits were having the highest score of 9.0 on the day of preparation. It showed a decreasing trend and the score was in the range of 7.95 -8.5 by the end of 5 days of preparation. The microbiological, sensory and nutritional shelf life of minimally processed vegetables or fruits should be at least 4-7 days (Ahveneviven, 2000). That was satisfied in the present study. Among the fruits, mango was having least score. But it may be due to the over ripeness of mango fruits selected for the study.

Fig.11. Textural change of f resh cut fruits during






Fi g 11 c. Cohesiveness
cohesiveness
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
mango
papaya
pineapple
pomegranate

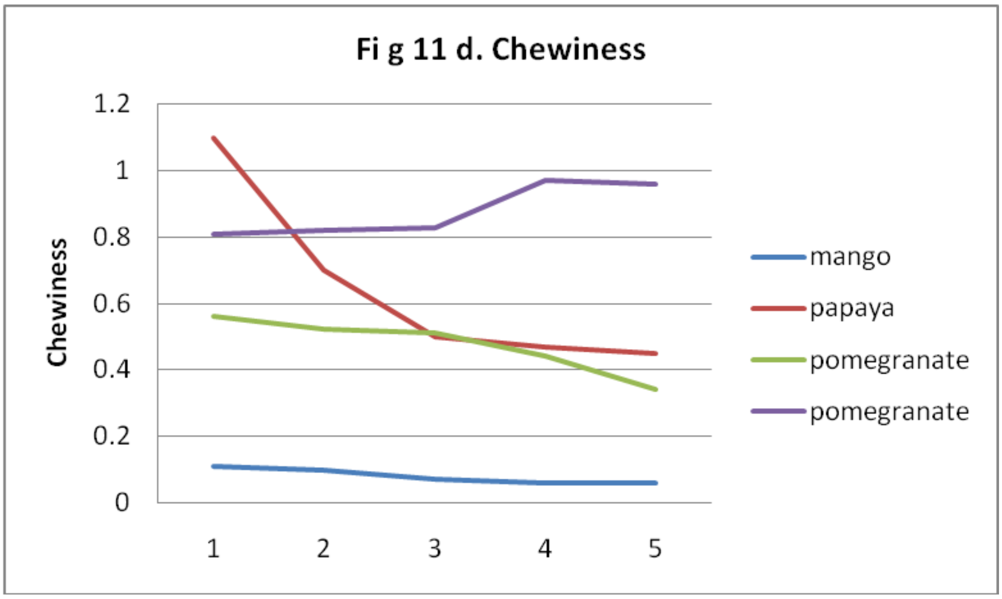
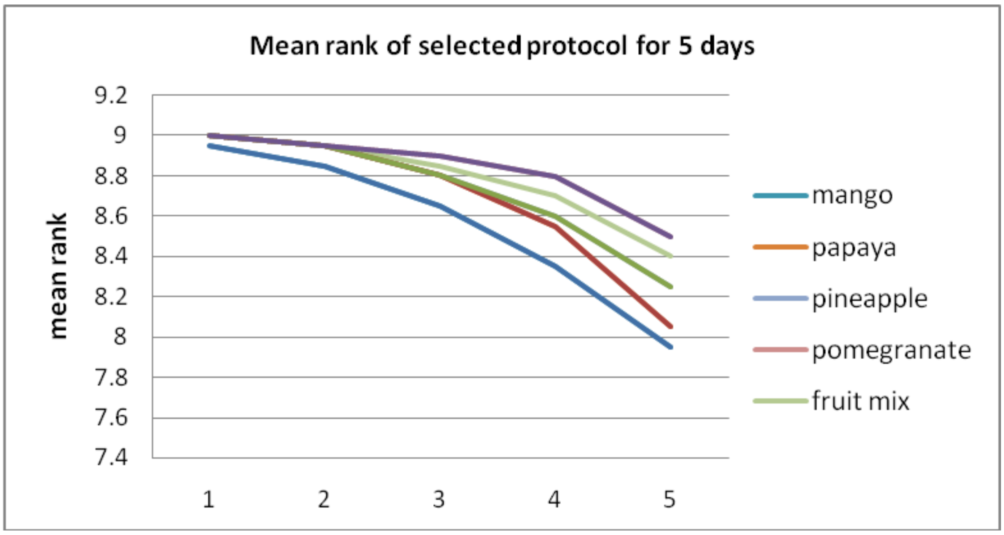

Fi g 11 d. Chewiness
Chewiness
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
mango
papaya
pomegranate
pomegranate

Fig 12.Mean score for fresh cut fruits and fruit mix prepared by standardized protocol



Whereas most food processing techniques stabilize the products and lengthen their storage and shelf life, production of fresh cut fruits increases their perishability (Beauchat,2000). Hence for increased sanitation, as well as for preparation and handling of these products, knowledge of food science and technology and post harvest physiology is a must.

Selection of raw material with proper maturity is another important criterion for fresh cut fruit preparation. Improper maturity and storage leads to faster senescence resulting in colour changes and loss of firmness leading to reduction in market value. Fruits, which are at correct ripeness, when packed, will become overripe within two three days affecting its firmness. Hence the fruits meant for fresh cut preparation should be properly mature and slightly under ripe when packed in the packaging trays. Fruits at that particular stage will be ready for consumption within one or two days of storage.

Summary

5. SUMMARY

The present investigation on "Protocol development for fresh cut fruits & fruit mix preparation" was carried out at the Department of processing Technology, College of Agriculture, Vellayani, during 2010-2012, with the objective to standardize an efficient and economic protocol for development of fresh-cut fruits and fruit mix with extended shelf life and to study the acceptability of the standardized technology. Major findings of the study are summarized below.

Protocol for fresh cut fruit preparation includes surface sanitization, pre-treatment of cut pieces, packaging and storage. The investigation was carried out as four different continuous experiments viz., evaluation of different sanitizing agents, evaluation of different pre-storage treatments, development of packaging system followed by testing the acceptability of standardized technology. Mango, papaya, pineapple and pomegranate were used individually and in combination.

The efficacy of different sanitizing solutions on surface decontamination of fruits was investigated. Surface sanitization with sodium hypochlorite at the highest concentration of 120 ppm resulted in least number of bacterial population in mango, papaya and pineapple. But 120 ppm was on par with 90ppm and 60ppm solutions in mango. In papaya and pineapple, 120ppm was on par with 90ppm solution. In Pomegranate, sanitization with all concentrations of sodium hypochlorite solution was equally effective. Based on the efficiency of sanitizers in reducing the bacterial load and economics, the lowest concentrations of sanitizers were selected for further study. In mango, 60 ppm sodium hypochlorite solution was selected; 90 ppm solution was selected for papaya and pineapple and 30 ppm for pomegranate. Untreated pineapple and papaya had highest bacterial population which was on par with pineapple sanitized using 40^0C water. In mango also, sanitization using 40^0C water had highest number of bacterial population.

Effect of different pre storage treatments on physical, physiological and chemical quality parameters of fruit pieces was evaluated along with their efficiency to control microbiological growth.

Treated fresh-cut mango pieces were having low physiological loss in weight compared to untreated cut mango pieces. Osmotic potential was least for pieces treated with calcium chloride, calcium ascorbate, sodium acid sulphate or KMS and citric acid. Calcium chloride treated cut mango pieces had least percentage leakage too making it firm in texture. Calcium chloride treated fruit pieces obtained maximum score for appearance and texture in sensory scoring also.

Cut mango pieces treated with KMS+ascorbic acid had highest osmotic potential and percentage leakage, hence considered inferior as a pre- treatment for mango pieces. Mango fruits treated with this chemical had low score of overall acceptability in physical analysis too. Fresh cut mango pieces treated with 0.1% KMS+ citric acid exhibited least acidity and highest TSS content. Calcium ascorbate treated fruits had highest TSS, vitamin C, carotenoid content and high starch and they had high organoleptic score for sensory parameters like appearance, flavour, texture and taste also.

Mango pieces treated with sodium acid sulphate had least TSS and highest carotenoid content. As the phenol content was minimum, sodium acid sulphate treated mango pieces scored maximum for colour, though it had least score for texture, taste and juiciness. Cut mango pieces treated with 0.1% KMS+ ascorbic acid had highest phenol there by exhibiting low score for colour during physical analysis. Though untreated fresh cut mango pieces recorded least starch and vitamin C content, it had maximum total soluble solids and minimum phenol content. Cut papaya pieces treated with 0.1% KMS + 0.1% citric acid had least physiological loss in weight and percent leakage, hence recording highest score for appearance in sensory scoring. Papaya pieces treated with 0.1% KMS + 0.1% ascorbic acid also had least percent leakage.

Treatment with 3% sodium acid sulphate also could lower the physiological loss in weight and percent leakage in cut papaya samples. But the cut papaya pieces treated with this chemical had highest acidity and lowest Total Soluble Solids, hence had low scores for appearance, flavour, taste and juiciness. Vitamin C content was also lowest for those papaya pieces. TSS were highest and vitamin C was least for untreated cut papaya pieces. Vitamin C content of cut fruit pieces could be improved by treating with chemicals containing vitamin C, viz., calcium ascorbate or 0.1% KMS + 0.1% ascorbic acid.

Physiological loss in weight and percent leakage were minimum for calcium chloride treated cut pineapple pieces, thereby giving firmness to the sample. Percent leakage was least for pineapple pieces treated with 0.1% KMS and 0.1% citric acid and calcium ascorbate. Fruit pieces treated with these two chemicals showed superior performance in physical analysis too. Pineapple pieces treated with 0.1% KMS + 0.1% citric acid had obtained highest score for appearance and total freshness, whereas those treated with 1% calcium ascorbate had highest score for taste and juiciness.

Untreated cut pine apple pieces had the highest total soluble solids and they were least acidic compared to treated pineapple pieces. Pineapple pieces treated with 1% calcium ascorbate had the highest vitamin C and high total soluble solids. Total phenol was least for fresh cut pine apple pieces treated with 3% sodium acid sulphate. Sodium acid sulphate treated fresh-cut pineapple had highest score for colour and flavour in evaluation of physical parameters.

Physiological loss in weight, osmotic potential and percent leakage were least for the pomegranate arils treated with 1% calcium chloride. Pomegranate arils treated with calcium chloride were firm and succulent, exhibiting overall acceptability and juiciness in physical analysis too.

As none of the pre- treatments tried showed superior performance for all the quality parameters evaluated, the four pre-treatments having top weighted average ranks were selected for each fruit, for further microbial analysis. Among the top ranking treatments, calcium chloride and calcium ascorbate were selected for all the fruits. When fruit pieces treated with selected chemicals were subjected to microbial analysis, all the selected chemicals exhibited similar efficiency in microbial control. Pre-treatment having high weighted average ranks and capacity to reduce the microbial population, was selected as the efficient pre- treatment for each fresh cut fruit piece. Accordingly 0.1% KMS and 0.1% citric acid was selected as the best pretreatment for fresh cut mango and papaya pieces, where as 1% calcium chloride was selected for cut pineapple pieces and pomegranate arils. As calcium ascorbate is very costly, the chemical was not considered for selection, though it was effective.

Fresh-cut fruits were prepared using the best sanitizing and pre-storage treatment selected for each fruit, packed in different packaging materials and stored under refrigerated condition. In the case of fruit mix, 25 g of each fruit was given the respective sanitization and pre- treatment selected during the previous experiments and mixed together to form the fruit –mix.

When different packaging materials were compared, all the fruit samples kept in aluminium tray with or without $KMnO_4$ sachet and polystyrene tray had lowest physiological loss in weight and percent leakage, indicating their superiority. Unventillated or microventillated packages, with or without an ethylene absorbent, were not always good in maintaining physiological quality parameters of fresh cut fruits. All unpacked fruit pieces had highest physiological loss in weight.

Packaging in aluminium or polystyrene trays covered with cling film with or without keeping any $KMnO_4$ could maintain the quality parameters such as increased TSS, reduced phenol of all four fresh cut fruits. Retention of nutritional quality parameters like high carotenoid, starch and vitamin C was noticed in fruits packed in these containers. Unventilated or microventilated polyethylene or polypropylene with or without $KMnO_4$ sachet were found inferior to aluminium or polystyrene trays as it reduced the nutrient content of all fresh cut fruits and fruit mix studied.

Considering all physical, chemical and physiological parameters, the top ranking four packaging materials viz., aluminium tray and polystyrene tray with or without $KMnO_4$ sachet were selected for further microbial analysis. When microbial population was analysed, both bacterial and fungal population were similar in cut mango or pineapple pieces and pomegranate arils kept in all the packaging materials. Addition of ethylene absorbent could not make any added advantage on the microbial control.

Combining all the treatments protocol for fresh-cut fruit production was standardized for mango, papaya, pineapple, pomegranate.

Mango - Surface sanitization using 60ppm sodium hypochlorite for 15 minutes followed by treating ≈ 2cm cube pieces with 0.1% KMS and citric acid for 10 minutes and refrigerated storage after packaging in aluminium tray covered with cling film.

Papaya - Surface sanitization using 90ppm sodium hypochlorite for 15 minutes followed by treating ≈ 2cm cube pieces with 0.1% KMS and citric acid for 10 minutes and refrigerated storage after packaging in aluminium tray covered with cling film.

Pineapple - Surface sanitization using 90ppm sodium hypochlorite for 15 minutes followed by treating ≈ 2cm cube pieces with 1% calcium chloride for 10 minutes and refrigerated storage after packaging in aluminium tray covered with cling film.

Pomegranate - Surface sanitization using 30ppm sodium hypochlorite for 15 minutes followed by treating the extracted arils with 1% calcium chloride for 10 minutes and refrigerated storage after packaging in aluminium tray covered with cling film.

Fruit mix could be prepared by giving corresponding sanitizer and pre-storage treatments selected for 25g each individual fruits, followed by refrigerated storage after packaging in aluminium tray covered with cling film.

Cost of production of 1 kg. fresh-cut fruit and fruit mix was calculated.

Textural quality and colour change of the prepared fresh cut fruits were analysed by instrumental methods. Total colour change was increased and yellowness index was decreased in five days. Regarding textural parameters; springiness and chewiness showed a slight reduction and cohesiveness showed a slight increase. Though these parameters were slightly changed, firmness showed a drastic reduction in five days. Even then fresh-cut fruits and fruit mix prepared as per the standardised protocol were acceptable to the sensory panel even at the end of fifth day.

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Abstract

PROTOCOL DEVELOPMENT FOR FRESH-CUT FRUITS AND FRUIT MIX PREPARATION

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(2010-12-112)

ABSTRACT

of the thesis submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE
(Processing Technology)

Faculty of Agriculture

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2012

ABSTRACT

The present investigation on "Protocol development for fresh- cut fruits and fruit mix preparation" was carried out at the Department of processing Technology, College of Agriculture, Vellayani, during the period of 2010-2012, with the objective to standardize an efficient and economic protocol for development of fresh- cut fruits and fruit mix with extended shelf life and to study the acceptability of the standardized technology.

Protocol for any fresh- cut fruit preparation includes surface sanitization of whole fruit, removal of inedible portions and cutting into pieces of required sizes, pre-treatment of cut pieces, air drying, packaging and storage. The investigation was carried out as four different continuous experiments viz., evaluation of different sanitizing agents, pre-storage treatments, development of packaging system followed by testing the acceptability of standardized technology. Mango, papaya, pineapple and pomegranate were used individually and in combination.

Investigation on the efficacy of different sanitizing solutions on surface decontamination of fruits revealed that highest concentration of 120 ppm is effective in reducing the bacterial population in mango, papaya and pineapple. All concentrations of sodium hypochlorite solution were equally effective in pomegranate.

Studies on the effect of pre storage treatments on physical, physiological and chemical quality parameters of fruit pieces and arils revealed superiority of calcium treatments. One per cent calcium chloride or calcium ascorbate had least percent leakage, physiological loss in weight and osmotic potential, making the pieces and arils firm in texture. Combination of preservative and acidulant also maintained the freshness and quality of fresh-cut samples. Pre storage treatment with 0.1% KMS or

sodium benzoate and 0.1% citric acid or ascorbic acid was considered superior. Fruit pieces with superior physical and chemical parameters scored high in sensory analysis too. None of the pre- treatments showed superior performance for all the chemical quality parameters evaluated.

Among the chemicals evaluated, calcium ascorbate was very costly and sodium acid sulphate imparted acidic taste to the product, though they were superior in maintaining the quality of fresh- cut fruits.

When different packaging materials were compared, all the fruit pieces and pomegranate arils kept in aluminium tray with or without $KMnO_4$ sachet and polystyrene tray had lowest physiological loss in weight and percent leakage, indicating their superiority. They could maintain the quality parameters such as increased total soluble solids, reduced phenol of all four fresh- cut fruits. Unventillated or microventillated packages, with or without an ethylene absorbent, were not always good in maintaining physiological quality parameters of fresh- cut fruits. All unpacked fruit pieces had highest physiological loss in weight. The packaging materials did not have influence on microbial population. Addition of ethylene absorbent could not make any added advantage on the microbial control.

The most efficient and economic protocol was developed for each fruit, which could give a shelf life of five days.

Fresh- cut mango can be prepared by surface sanitization using 60 ppm sodium hypochlorite for 15 minutes followed by treating ≈ 2 cm cube pieces with 0.1% KMS and citric acid for 10 minutes and refrigerated storage after packaging in aluminium tray. Papaya could be stored using the same protocol, except sanitization using 90 ppm sodium hypochlorite. In pineapple, surface sanitization using 90 ppm sodium hypochlorite and pre storage treatment with 1% calcium chloride was effective.

Pomegranate arils could be stored using the same protocol, except sanitization using 30 ppm sodium hypochlorite. Fruit mix could be stored in similar packaging material under refrigerated condition after giving the corresponding sanitization and pre treatment selected for individual fruits.

Quality parameters and cost of production of the prepared fresh- cut fruits and fruit mix were analysed and the samples were acceptable to the sensory panel even at the end of fifth day.

Appendices

APPENDIX I

Kerala Agriculture University
College of Agriculture
Department of Processing Technology

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF FRESH-CUT FRUITS AND FRUITMIX

Name of student: Amith P.K. (2010-12-112)
Title Of Thesis: Protocol development for fresh-cut fruits and fruit mix preparation

Criteria	SAMPLES				
	1	**2**	**3**	**4**	**5**
Appearance					
Colour					
Flavour					
Texture					
Taste					
Overall acceptability					

SCORE

Like Extremely	-9
Like Very Much	-8
Like Moderately	-7
Like Slightly	-6
Neither Like Nor Dislike	-5
Dislike Slightly	-4
Dislike Moderately	-3
Dislike Very Much	-2
Dislike Extremely	-1

Date :

Name :

Signature: