EVALUATION OF FRUIT WASTES AS SOURCES OF PECTIN

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Evaluation of fruit wastes as sources of pectin"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Evaluation of fruit wastes as sources of pectin"** is a record of research work done independently by **Miss. Apsara Madhav**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Fruit wastes, which are highly perishable and seasonal, is a problem to the processing industries, pollution monitoring agencies and also to people who are concerned about its disposal. It is not only a problem, but a nuisance or menace as well and therefore suitable methods have to be adopted to utilize them for the conversion into value-added products (Nand, 1998).

Profitable exploitation of fruit wastes into value added by-products improves the overall economics of processing units by reducing the cost of production of main products. Thus by-product recovery can either offset the cost or increase the cash flow or both. Besides this, the problem of environmental pollution also can be reduced considerably.

A valuable by-product that can be obtained from fruit wastes is pectin. Pectins are mixtures of polysaccharides that originate from plants, contain pectinic acids as major components and are water-soluble.

Pectin substances are of interest to scientists of postharvest technology because of their important role in maintaining the texture of raw and processed fruits and vegetables. Pectins exist in varying amounts in fruit cell walls and have important nutritional and technological properties, mainly because of their ability to form gels (Westerlund *et al.,* 1991). Pectin is obtained mainly from by-product or waste streams of the processing of apple, orange and lemon juices (Kratchanova *etal.*, 1991). It is a polysaccharide composed primarily of essential linear polymers of D-galactopyranosyl-uronic acid units joined in α-D (1,4) glycosidic linkages (Be Miller, 1986). Gel formation results when the polymer chains interact over a portion of their length to form a three dimensional network. This property raised pectins to a commercially important value added product.

The pectin is used in manufacturing jams, jellies, marmalades, preserves etc. It is also useful as a thickening agent for sauces, ketchups, flavoured syrups and as a texturising agent in fruit-flavoured milk desserts. Besides, it finds numerous applications in pharmaceutical preparations, pastes, cosmetics etc. It is also used as an emulsifying agent in the preparation of products like cod liver oil, ice cream etc and can be used to increase the foaming power of gases in water and also to glaze candied fruit (GITCO,1999).

Pectin is a structural cell wall polysaccharide of all higher plants. Like most other polysaccharides, it is both poly molecular and poly disperse because it is heterogenous with respect to both chemical structure and molecular weight. From molecule to molecule, in any sample of pectin, both the number and percentage of individual monomeric unit types will vary and the average composition and distribution of molecular weight can vary with the source, the condition used for isolation and any subsequent treatments. So standardisation of suitable isolation techniques are very important for the extraction of maximum quantity of quality pectins.

The suitability of pectins for different purposes are determined by their characters viz., anhydrouronic acid content, methoxyl content, degree of esterification and acetyl value. These characters largely influence the jelly grade of pectins, which determines its commercial value. Jelly grade is the amount of sugar that will jellify one part of pectin under prescribed conditions to a standard firmness. Hence it is an unavoidable aspect that every pectins should be described properly through characterisation.

It is worth mentioning that the single largest use of pectin is in the manufacture of jelly. About 80 to 90 per cent of the seven million kilogram of commercial pectin is used to make jelly and similar products. So the best way of evaluating the commercial validity of pectins is by testing their suitability for preparation of jelly.

As the conditions of the media (mainly sugar acid ratio), boiling time and temperature largely influence the quality of jelly and are specific to specific pectins, preparation condition for jelly also require standardisation.

The fact that majority of pectin produced in the world is extracted from waste (peels) materials of lime processing industries is an inspiration to this work. New sources of pectin identified will be helpful to the Indian processing industries in the present context, when we are still importing about 160 tonnes of pectins valued at about ten crores of rupees for use by fruit and vegetable processing industries.

The aim of the present investigation was to:

- identify methods for maximum extraction of pectin from different fruit wastes
- evaluate these potential pectin sources for pectin yield and quality
- assess jelly forming potential of these pectins and
- evaluate their storage stability.

Review of Literature

REVIEW OF LITERATURE

Fruits, being rich sources of vitamins and minerals, besides other nutrients, are important in the nutrition of people all over the world. But, about 20-40 per cent of these are lost due to lack of good scientific management.

The maximum value from these perishable foods may be obtained by utilizing every bit of the produce, including the wastes generated from them.

2.1 Importance of fruit waste utilization

According to Bhalerao and Mulmuley (1989), the inedible portions of fruits, which are discarded by consumers and fruit processing units go as waste. A variety of value added products can be manufactured if wastes are utilized in an organised manner. The wastes produced by one manufacturing process will serve as raw material for the other process, by converting these into by-products. By-product recovery from the wastes offset the cost or even increase the cash flow, thus making the industry economically more viable and help in saving foreign exchange.

Joshi and Joshi (1990) reported that rapid industrialization in the field of agriculture and processing of agricultural produce resulted in waste generation and has invited environmental problems.

Efficient utilization of fruit wastes can help in minimising pollution hazards, supply of vital nutritional components in foods, making by-product recovery possible, increasing the cash flow and thereby increasing the income of the processor. Also, wastes can be efficiently disposed and capacity utilization of processing units can be increased (Srivastava and Sanjeevkumar, 1994 and Anand and Maini, 1997).

According to Girdharilal *et al.* (1998), large quantities of waste materials are left over during the canning of fruits and the preparation of juices, squashes, jams jellies, dried products etc. These materials have to be profitably utilized for the manufacture of by-products in order to reduce the cost of production of the main products.

2.2 Generation of wastes from different fruits and their utilization

Some parts of the fruits are generally discarded as wastes whenever they are consumed. According to Bhalerao and Mulmuley (1989), during fruit processing, more than 50 percent of the fruit weight goes as waste in the form of peel, pulp, fruit stones etc. These wastes offer many opportunities for its direct conversion into by-products, which are essentially required by the industry as raw materials. Pectin, citric acid, natural colouring pigments (carotenoids), mango fat (substitute for cocoa butter), essential oils and flavours are some of the examples. Thus a variety of value added products can be manufactured, if wastes are utilized in an organised manner.

2.2.1 Mango

Mango peel is a rich source of pectin (13 to 18%) and it can be utilized for commercial exploitation of good quality pectin which can be utilized for the production of jelly of good quality (Krishnamurthy, 1980., Anand and Maini, 1997., Sudhakar and Maini, 1999 and Ramteke *et al.,* 1999).

Sounder and Chandra (1987) reported that during processing of mangoes, over 50 % waste is generated in the form of peel, stones and pulp fibres.

Alfani and Cantarella (1987) and Larrauri *et al.* (1996) opined that mango peel is a good source of tropical fruit fibre.

According to Bhalerao and Mulmuley (1989) and Srivastava and Sanjeevkumar (1994), varied products viz., carotenoid pigments, vinegar and wine can be prepared from mango peel, whereas from kernels, tanins and starch can be produced.

Ethiraj and Suresh (1992) and Girdharilal *et al.* (1998) reported that dietary fibre as well as vinegar having mild mango flavour can be produced from peels. From the adhering pulp on mango stone, vinegar, wine and leather can be made.

According to Tandon and Kalra (1989), mango peel and stones may be processed into value added products such as pectin, starch, oil and poultry feed. Jam also can be prepared from mango peel (Pruthi, 1992). Garg *et al.* (1994) reported that mango peel is a complex organic substrate comprising of pectin, fibre, sugars, fats and minerals.25 to 30 per cent of the fruit is wasted in the form of peels during canning (Srivastava and Sanjeevkumar, 1994., Girdharilal *et al.*, 1998 and Sudhakar and Maini, 1999).

Anand and Maini (1997) reported that during the processing of over 10 million tonnes of mango fruits produced in India, for the production of important products viz., jam and squash, more than 50 percent waste is generated in the form of peel, stones and pulp fibre. Among the processing wastes, kernel constitute 15 to 20 per cent and peel 25 to 30 per cent.

2.2.2 Pineapple

Of the pineapple processing wastes, 40 to 50 per cent is constituted by peels, cores and pomace and cannery waste constitute 60 per cent (Devi and Ingle, 1982., Srivastava and Sanjeevkumar, 1994., Anand and Maini, 1997 and Girdharilal *et al.*, 1998). Devi and Ingle (1982) also reported the diversified uses of pineapple wastes. From mill juice, it is possible to produce bromelain, vinegar, wine and sugar syrup. Citric acid can be produced from mill juice by solid state fermentation of pineapple waste by *Aspergillus foetidus*. Candies can be prepared from pineapple cores. Pineapple wastes also can be employed for the production of oxalic acid by oxidation with nitric acid in presence of vanadium pentoxide catalyst.

Valuable by products such as bromelain, wine, oleoresin, hemicellulose, vinegar, biogas etc. can be manufactured from the waste materials obtained from pineapple processing industries (Joseph and Mahadeviah, 1988., Bhalerao and Mulmuley, 1989 and Joshi and Joshi, 1990)

Joshi and Joshi (1990) also reported that peels are good source of pectin, sugar and fibre.

Juice extracted from peels, trimmings and other wastes can be refined and used for canning pineapples. Citric acid, alcohol and vinegar can be prepared from this juice. The cores can be used for preparing candy or for extracting juice (Srivastava and Sanjeevkumar, 1994 and Girdharilal *et al.*, 1998).

Hegde (1997) reported that peel and pulp waste from pineapple can be used for producing Nata-de-Pina. The bacterium culture of *Acetobacter xylenum* is found capable of bio converting pineapple juice into gel known as Nata-de-Pina, which can be eaten as a dessert or it blends well with fruit salad, ice cream and puddings.

The wastes from pineapple processing industries-peels, cores and pomace contain about seven to ten per cent sugar and can be utilized for vinegar production. Peels are rich in sugar and fibre. Besides this, wastes can be utilized for the extraction of waxes and bromelain (Anand and Maini, 1997).

2.2.3 Jack fruit

Wastes such as rind and core could be commercially exploited for pectin extraction. Appreciable amounts of pectin were found in jackfruits (Varikka type) collected from different localities (Vilasachandran *et al.,* 1985)

Berry and Kalra (1988) reported that rind alone constitutes 59 per cent of the bulk of the fruit. During processing, rind, perigones and seeds are left as wastes, which is about 45 percent of the total weight (Anand and Maini, 1997 and Girdharilal *et al.,* 1998).

Different wasted parts of jackfruit have diversified uses. Thick rind and perigones are good sources of pectin and fibre. (Berry and Kalra, 1988., Srivastava and Sanjeevkumar, 1994., Anand and Maini, 1997 and Girdharilal *et al.,* 1998). Good flour as well as starch could be produced from seeds, which can be blended with cereal flours. Broken bulbs were found ideal for making leather. Berry and Kalra (1988) and Girdharilal *et al.* (1998) also opined that the sugar and pectin present in jackfruit rind make it suitable for the preparation of good quality jelly.

2.2.4 Banana

Peels from the processing factories contributes the major waste of the fruit (Mohamed and Hassan, 1995 and Girdharilal *et al.,* 1998) which accounts to about 22 to 30 % (Anand and Maini, 1997).

The pulpy portion of banana peel is reported to be good for making banana cheese (Srivastava and Sanjeevkumar, 1994 and Girdharilal *et al.,* 1998).

Mohammed and Hassan (1995) reported that pectin can be extracted from the banana peels.

2.2.5 Citrus

Citrus fruit wastes can be used for making by products such as pectin, essential oil and seed oil (Mehta and Bajaj, 1983., Sud and Badyal, 1993 and Anand and Maini, 1997). Mehta and Bajaj (1983) also reported that 50 per cent of the peel and pulp of citrus could be incorporated into comminuted squash without introducing peely flavour.

Bawa and Saini (1988) found that the residue obtained after juice extraction from Kumkaut (wild citrus) fruit is a rich source of pectin (2.57%) and ascorbic acid.

During the processing of citrus fruits, nearly 50 per cent of the fruit, comprising of peel and seeds evolve as wastes, of which peels alone constitute 20 to 30 per cent (Bhalerao and Mulmuley, 1989., Sud and Badyal, 1993., Srivastava and Sanjeevkumar, 1994 and Khurdiya *et al.,* 1997). Bhalerao and Mulmuley (1989) also reported that citrus juice sacs (lime and orange) and citrus pips, which are wasted by citrus juice industry could be used in the production of powdered mixes for enhancing consumer appeal.

Among the entire citrus wastes, orange waste alone comes to about 50 per cent (Cervera and Sanchez, 1993., Anand and Maini, 1997 and Girdharilal *et al.,* 1998). Shamel and Zoghbi (1993) opined that clouding agents are being produced from citrus peels utilising pectyolytic enzymes.

Citrus peels can be used for making candy and extraction of essential oils. From the rags of galgal and orange, pectin can be prepared. Rags can also be utilized in the preparation of marmalade and orange toffee. Seed oil can be extracted from orange and lime seeds, whereas from lime sludge, lime oil can be obtained. Citric ıcid can be prepared from lime sludge. Orange residues can be fermented into fruit /inegar (Srivastava and Sanjeevkumar, 1994 and Girdharilal *et al.*, 1998).

Widmer and Montanari (1995) reported the production of pharmaceutically mportant natural products including flavanones, methoxylated flavanones and pectin from citrus wastes.

Anand and Maini (1997) opined that majority of pectin produced in the world is extracted from citrus peels. Two citrus processing units in Uttrayan and Kodur are producing lime pectin. They also reported that mandarin essential oil is extracted at different processing units at Bangalore, Nagpur, Punjab and Sikkim whereas lime oil is extracted at Uttrayan, Jalgaon and Kodur. According to them, orange wastes are dried in Florida and California for use as livestock feed. The liquid concentrate made from crude citrus waste is similar to cane molasses and is widely used for feeding dairy and beef cattle. The Citrus World Incorporation in Florida recovered a 3,20,000kg of orange oil from six lakh tonnes of orange juice concentrate.

Khurdiya *et al.* (1997) remarked the suitability of lime pomace for producing carbonated beverages. Pectin, oil and citric acid are the other commercially exploited products from pomace.

Girdharilal *et al.* (1998) reported the diversified uses of citrus fruit wastes. Pectin can be prepared from the juice residues of galgal and orange. Fresh orange peels yield about 0.54 percent of oil by steam or water distillation. From citrus peels, a variety of by-products such as candied peel, peel juice for molasses, essential oils, pectin, citric acid and vitamin C can be prepared. Glucosides from the peel known as bioflavins are finding use as anti-oxidants and in physiological application. Citrates have been prepared from lemon peel. Seed oil, after refining can be used in cooking.

2.2.6 Guava

The pomace after extraction of pectin from guava fruits, contain enough amount of cellulosic material which can be used for producing citric acid through microbial fermentation (Kapoor *et al.*, 1982., Adsule and Kadam, 1995 and Garg *et al.*, 1998).

The core, seeds and the peel forms the wastes from guava processing industries (Srivastava and Sanjeevkumar, 1994 and Girdharilal *et al.*, 1998). According to them guava cheese, which can be used like halwa can be prepared from guava peels and pomace. Anon (1994) reported that guava is a rich source of pectin, vitamin C and other nutrients.

2.2.7 Papaya

Girdharlal *et al.* (1998) reported that in the processing of ripe papaya fruit, greenish fruit lanced for the collection of latex forms the waste. These can be used for pectin extraction. These are also good for making tuti-fruiti.

2.2.8 Passion fruit

According to Prasad and Chandra (1980), rind of passion fruit is a very good source of pectin. Srivastava and Sanjeevkumar (1994) and Girdharilal *et al.* (1998) reported that thick rind and seeds form the wastes from passion fruit. The rind can be used for pectin extraction whereas seeds can be utilized for oil extraction.

2.2.9 Apple

The pomace remaining after the extraction of juice and removal of cores, can be used for the preparation of pectin (2.5 to 3.4 per cent on fresh weight basis and

18.78 per cent on dry weight basis), cider and vinegar (Krishnamurthy, 1980., Bhalerao and Mulmuley, 1989., Srivastava and Sanjeevkumar,1994., Shah and Masoodi, 1994., Anand and Maini, 1997 and Girdharilal *et al.*,1998).

Shah and Masoodi (1994) remarked that about 20,000 tonnes of apple pomace is generated in processing factories, after producing the major product i.e. apple juice.

Girdharilal *et al.* (1998) reported that large quantities of dried apple pomace forms the basis for commercial production of pectin in the U.K, Denmark, Switzerland etc. Apple pomace, being a rich source of pectin, can be utilized for blending with fruits poor in pectin for the preparation of jams, jellies etc. which require additional pectin.

2.2.10 Grapes

According to Srivastava and Sanjeevkumar (1994) and Girdharilal *et al.* (1998), stems and pomace which constitute five to ten per cent of the fruit are main waste products from grape processing factories.

Srivastava and Sanjeevkumar (1994) explained the varied uses of wastes from grapes. Pomace can be used for pectin extraction. Oil can be extracted from seeds and left over cake used as cattle feed.

2.2.11 Nutmeg

The rind which is considered as a waste, constitute about 80 to 85 per cent of the whole nutmeg (Pruthi and Krishnankutty, 1985 and Krishnamoorthy *et al.*, 1991).

Nutmeg rind can be economically utilized for extracting pectin (Pruthi and Krishnankutty, 1985 and Gopalakrishnan, 1992). Using the pectin, jelly of good quality can be prepared. Joshi *et al.* (1996) successfully utilized nutmeg rind for standardising the different edible value added products such as preserve, candy, pickle, chutney and powder.

2.2.12 Cocoa

According to Haryali and Harjosuwito (1984) and Mohamed and Hassan (1995), cocoa bean shells are rich source of pectin. The average pectin content in it was found to be 7.15 per cent. Cocoa pod husks are the waste materials remaining after the separation of cocoa beans (Nambudiri and Shivashankar, 1985 and Mohamed and Hassan, 1995).

Nambudiri and Shivashankar (1985) compared the pectin content in cocoa with that of orange pulp; lemon pulp and apple pomace. According to them, the dry pod husk contains 5.3 to 7.08 per cent pectin, which is high compared to orange pulp (3.5 to 5.5 per cent), lemon pulp (2.5 to 4.0 per cent) and apple pomace (1.5 to 2.5 per cent). They also found that cocoa pod husks are used in animal feeds, fertilizers and for paper manufacture.

2.2.13 Phalsa

The water extract of phalsa pomace is suitable for producing carbonated beverages (Waskar and Khurdiya, 1993). Khurdiya *et al.* (1997) reported that depending on the type of fruits, the recovery of phalsa pomace ranges from 30 to 60 per cent.

2.2.14 Apricot

The waste material obtained are peels and kernels. The peels are widely in use for making wine. From the kernels, kernel oil can be extracted, which after refining, can be used in pharmaceutical and cosmetic preparation (Girdharilal *et al.*, 1998)

2.2.15 Peach and pear

Srivastava and Sanjeevkumar (1994) and Girdharilal *et al.* (1998) reported that the wastes obtained from peach are the kernels, whereas peels and cores are the wastes from pear. According to Girdharilal *et al.* (1998), seeds of peach fruits are good source of oil, which is having many industrial uses. Perry and vinegar-the fermentation products of pear fruits can be prepared with peels and cores of pear.

2.2.16 Watermelon

Crandall and Kesterson (1981) reported that watermelon rind yielded 20 per cent pectin on dry weight basis. According to Singh and Bains (1981), watermelon seeds can be used for oil extraction. Uddin and Swamy (1981) described the preparation of preserves and candies from the white rind of watermelon.

Kumar (1995) studied the probability of utilization of watermelon peel for pickle processing. Watermelon rind can be processed to prepare candy (Teotia *et al.*, 1988). Bhatnagar (1991) reported that rind of watermelon is a good source of pectin. The pectin amounts to 0.98 per cent.

2.3 Extraction of pectin from fruit wastes

Different methods are employed for extracting pectin from different fruit wastes. The recovery and quality of pectin from a plant material depends upon a number of factors like the nature and concentration of acid employed in the extracting media, the ratio of the extracting media to the plant material, the number of extractions, the time of heating for pectin extraction etc. (Pruthi and Krishnankutty, 1985 and Sudhakar and Maini, 1999).

According to Pruthi and Krishnankutty (1985), for the manufacture of pectin, generally hydrochloric acid and citric acid are used.

Doner (1986) suggested that the pectic substances can be extracted with water, dilute acid or with calcium chelating agents such as EDTA, ammonium oxalate or sodium hexa meta phosphate.

Garleb *et al.* (1991) isolated pectic substances from three sources of apple, cucumber, celery, grape fruit and raddish with ammonium oxalate and analysed for galacturonate and neutral monosaccharides.

Turakhozhaev and Khodzhaev (1993) isolated pectin from plant sources using preliminary treatment of the raw material, hydrolysis of proto pectin and pectin extraction using acid, salt and alkali solutions.

2.3.1 Mango peel

Kalra and Tandon (1985) extracted pectin from dry peel and kernel of immature and ripe Dashehari mangoes using 0.05 N NaOH, 0.05 N HCl and 0.3% sodium hexa meta phosphate. Maximum yield of 12.79% pectin was obtained in ripe mango peel from sodium hexa meta phosphate extraction and the kernel was found to contain very little amount of pectin.

Pedroza-islas *et al.* (1994) reported that highest pectin yield from mango peels was obtained at pH-3, bleaching with alcohol and an extraction time of 60 minutes.

Method of extracting pectin from mango peels was standardised by Sudhakar and Maini (1999). After thorough washing of the peel, the extraction was carried out by boiling the peels in dilute acids, followed by separation of the extract by filtration. The pectin was then precipitated by adding two times of acidified alcohol. To make the pectin in powder form, the precipitated pectin was filtered off from the ethanol water mixture and dried at low temperatures under vacuum.

2.3.2 Jackfruit rind

Mohamed and Hassan (1995) tried the extraction of pectin from jackfruit rind using ethanol, metallic salt and acetone. Acetone was found better than the other two for pectin extraction.

Girdharilal *et al.* (1998) extracted pectin from rind and core of jackfruit after washing with 0.1% KMS and 0.05% HCl. The extraction was carried out with N/60 to N/50 HCl. Three extractions were taken at 97 to 100°C by heating the material for half an hour each time.

2.3.3 Pineapple peel, banana peel and cocoa pod husk

Among the various solvents tried for extracting pectin from pineapple peel, banana peel and cocoa pod husk, Mohamed and Hassan (1995) found acetone as the best compound to ethanol or metallic salt in all the cases in terms of yield, colour and gelling characteristics of pectin.

2.3.4 Wasted guava fruits

Extraction of pectin from winter guavas cv. Sardar at the mature unripe stage (fruit pressure > 8.5 kg per cm^2) and at the partially ripe stage (6.410 kg per cm^2) was found improved by sodium hexa meta phosphate, ammonium oxalate and HCl. The most effective of the aids to pectin extraction was ammonium oxalate (Dhingra and Gupta, 1984).

2.3.5 Citrus peels

Method for extracting pectin from the residue obtained after the extraction of carotenoids from orange peel was standardised by Aravantinos *et al.* (1992). Pectin was extracted from such peels using nitric acid. Carotenoid removal from peels was not found to affect the yield and quality of pectin.

Alcohol insoluble solids were prepared from orange peel by extraction with 0.5 M HCl in a Fibertec-1 semi automated extraction system for 30 minutes (King, 1987).

Atri and Maini (1996) standardised the process of extraction and recovery of pectin from the peel of *Citrus pseudolimon*. Peel in the powder form extracted twice with 0.1 N HCl maximize the recovery of pectin. For precipitation of pectin, alcohol was found better than aluminium chloride. The quality of dry powdered pectin was found preserved even after storage for six months.

Girdharilal *et al.* (1998) standardised the method of extraction of pectin from citrus peels. The sliced peel after washing with HCl and KMS was found to be good source for pectin extraction using N/50 HCl at temperature 97 to 100°C for 30 minutes to one hour.

2.3.6 Wasted papaya fruits

Girdharilal *et al.* (1998) reported that papaya after cutting and washing with 0.1% KMS and 0.05% HCl, could be used for extracting pectin with N/60-N/50 HCl. Pectin recovery was found to increase with repeated extractions.

2.3.7 Nutmeg rind

Pruthi and Krishnankutty (1985) reported that HCl is better than citric acid for extraction of pectin from nutmeg rind. They standardised the optimum time for pectin extraction as 60 minutes. More than 93% of the total pectin in nutmeg pericarp could be extracted using 0.25 percent HCl and 0.75% citric acid (with citric acid, two extraction steps are necessary). The pectin extracted using this method was found to be of good quality.

2.3.8 Apple

Beirne *et al.* (1982) reported that after removal of water soluble pectin from senescent apple fruits, an additional sizeable pectin fraction could be extracted using sodium-ethylene diamine tetra acetic acid under non degradative conditions.

Renard *et al.* (1991) extracted pectic material from apple cell walls successfully using hot buffer, hot acid and cold dilute sodium hydroxide or by buffer, arabinases, galactanase and pectin-lyase. Pectin-lyase extracted the highest amount of uronic acid. Dilute sodium hydroxide, solubilizing 34% of uronic acid was found as the most efficient chemical treatment.

Alcohol insoluble solids from Golden Delicious apples were extracted in sequence by buffer at 20° C and at 70° C, EDTA/oxalate and mild alkali by Schols *et al.* (1995).

2.4 Characterisation of pectin

2.4.1 Mango peel pectin

Studies on the yield, methoxyl content, anhydrouronic acid content, degree of esterification, molecular weight, setting time and jelly grade had shown that pectins from fruit peels of the mango cvs. Dashehari and Langra are comparable with pectins from other sources (Srirangarajan and Shrikhande, 1979).

Tandon and Kalra (1991) extracted pectin from mango peels using sodium hexa meta phosphate and evaluated in terms of moisture, equivalent weight, methoxyl content, relative viscosity and jelly grade and was found to be good. The water soluble pectin was more in peel of ripe fruits while alkali soluble fraction was maximum in peel of immature fruits.

Sudhakar and Maini (1999) reported that the pectin yield from citrus sources other than lime and lemon peels is lower than that of mango peels. The high methoxyl (8.6%) and degree of esterification (76.5%) values of pectin obtained from mango peels revealed good quality of pectin.

2.4.2 Guava pectin

Maximum anhydrouronic acid was found present in pectin extracted using 0.25% sodium hexa meta phosphate from unripe guava fruits and 0.075N HCl from partially ripe fruits. Stage of ripening was not found to affect methoxylation or AUA content (Dhingra and Gupta, 1984).

2.4.3 Citrus peel pectin

Alexander and Sulebele (1980) isolated pectins from lime, bitter orange, sweet orange and grape fruit peels, using acid extraction method and calculated jelly grade, setting time, molecular weight, degree of esterification, methoxyl content, acetyl value, anhydrouronide content and viscosity of the different pectins. Among pectin from different sources, lime pectin had shown rapid setting and high viscosity.

Baldwin and Biggs (1988) found that pectin fragments resulting from partial acid hydrolysis or pectolyase digestion caused an increase in ethylene production when injected into the peels of intact orange fruits.

2.4.4 Nutmeg rind pectin

The pectin extracted from nutmeg rind using 0.25% HCl and 0.75% citric acid was found of good quality (Pruthi and Krishnankutty, 1985).

2.4.5 Apple peel pectin

Beirne *et al.* (1982) reported that the galacturonic acid rich polymers of chelator-soluble pectin in apple were notably lower in arabinose, galactose and rhamnose residues than those of water soluble pectin.

Ayyad *et al.* (1990) reported that commercial apple pectins when irradiated with gamma rays at a dose of 2 KGy (200 K rad) increased the content of anhydrouronic acid and decreased the degree of esterification, methoxyl content and viscosity.

The pectins extracted using EDTA were characterised by their sugar composition, degree of esterification, methoxyl content and degradability by the combination of endopolygalacturonase and pectin esterase and by rhamno galacturonase after chemical saponification (Schols *et al.*, 1995).

Khalikov *et al.* (1995) studied the hydrolysis of apple protopectin with respect to changes in the amounts of monosaccharide residues of the reaction products. Increasing the time of hydrolysis was found to increase the amount of D-galacturonic acid units and viscosity. The fine regulation of the physicochemical parameters of the hydrolysis of protopectin led to the formation of pectic substances with different properties.

2.4.6 Cherry fruit pectin

Thibault (1983) found that the pectic substances extracted from cherry fruits appeared to consist largely of an alpha-D-galacturonic backbone interspersed with occasional L-rhamnosyl residues.

Materials and Methods

MATERIALS AND METHODS

The research work entitled "Evaluation of fruit wastes as sources of pectin" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara from 1999-2001. The study was conducted with the objective of evaluating the yield and quality of pectin from different fruit waste materials and assessing the quality of jelly prepared using these pectins. The materials used and the methods adopted for the study are described hereunder.

The study was carried out in a sequence as given below:

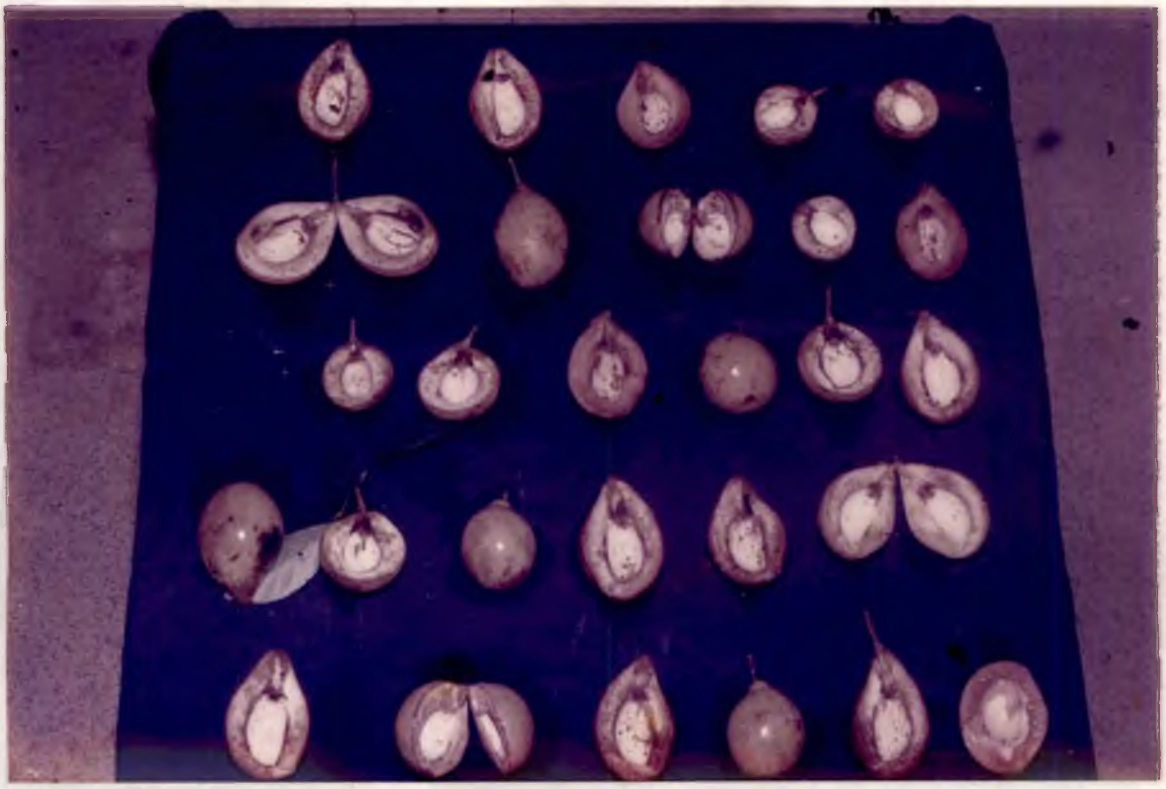
- Collection of fruit wastes and their primary processing
- Evaluation of different methods for pectin extraction
- Quantification of pectin content in different fruit wastes
- Characterisation of pectin obtained from different sources
- Preparation of jelly and its quality evaluation
- Upgradation of the jelly quality through special treatments
- Evaluation of shelf life of jelly

3.1 Collection of fruit wastes and their primary processing

The different fruit wastes collected for pectin extraction (Plate1) and their source of collection are given below.

Fruit waste	Source
1. Jackfruit rind	Farmer's field
2. Nutmeg rind	Farmer's field
3. Passion fruit rind	Farmer's field
4. Mangosteen rind	Farmer's field
5. Pumello peel	

Plate 1. Different fruit wastes evaluated for pectin content



6. Mango peel
7. Pineapple peel
8. Citrus peel
9. Banana peel

} Processing unit, Dept. of Processing Technology, College of Horticulture

10. Cocoa pod husk — Cadbury Cocoa Research Project, College of Horticulture

Fruits were collected at early ripe stage for pectin extraction.

3.1.1 Pre-treatments given for different fruit wastes

The pre-treatments given for different fruit wastes before pectin extraction are given below:

Jack fruit rind

The rind of jackfruit, including the perigones, which were left over after taking the fruit bulbs for various purposes, were minced into small pieces and washed well.

Mango peel

The peels obtained from mango fruit were washed thoroughly for removing the adhering pulp.

Pineapple peel

The peels obtained after taking the pulp were cut into small pieces and washed thoroughly to remove the adhering pulp.

Banana peel

The peels obtained from banana were scraped off to remove the pulp adhering on it and then cut into small pieces and washed well.

Pumello peel

After removing the juicy placental hairs, the rind was made free of oily green skin and only the cushiony part of the peel was taken after washing.

Lime peel

The rind of lime peel after juice extraction was washed and cut into small pieces.

Passion fruit rind

The rind of passion fruit was cut into small pieces and washed, after taking the juice and seed portion inside.

Cocoa pod husk

The cocoa pod husk obtained after removing the beans, was made into chips and washed well.

Nutmeg rind

The rind obtained after removing the seed with mace was cut into small pieces and washed well.

Mangosteen rind

The rind was obtained by cutting the fruit and removing the edible part inside. The rind was then cut into small pieces and washed well.

Three separate samples consisting of two kilogram each were weighed from different lots and used for pectin extraction.

3.2 Evaluation of different methods for pectin extraction

Pectin extraction was carried out by using citric acid, hydrochloric acid and sodium hexa meta phosphate as detailed below.

i. Citric acid

Citric acid was used at 0.5 and 0.75 percent, at the rate of 5 g per kg of the waste material.

ii. Hydrochloric acid

Hydrochloric acid at 0.1 and 0.3 N was used at the rate of 5ml per kilogram of waste material.

The citric acid and hydrochloric acid at different levels specified above were added with one and half as well as three litres of water per kilogram of the sample and boiled gently for different periods viz., 45 and 60 minutes.

iii. Extraction with sodium hexa meta phosphate.

Macerated the fresh fruit waste in a mixer-grinder and weighed 100g of it. This was mixed with water at the rate of 400ml for every 100g of sample. Sodium hexa meta phosphate was added to the mass at the rate of 1.2g for 100g of sample. The extraction time given was one hour, at 90-95°C (Ranganna, 1986). The p^H was maintained at 4.5 throughout the time of extraction, by adjusting with citric acid or sodium hydroxide according to necessity. To aid filtration, ground paper pulp was added to the extracting medium at the rate of 4g per 100g of the macerated fruit waste. The whole mass was filtered through a muslin cloth to obtain the pectin extract.

Thus the treatments were as shown below.

Treatments	Extractant	Quantity of water added (l \ kg of sample)	Extraction time (minutes)
T_1	Citric acid 0.5%	1.5	45
T_2	”	”	60
T_3	”	3	45
T_4	”	”	60
T_5	Citric acid 0.75%	1.5	45
T_6	”	”	60
T_7	”	3	45
T_8	”	”	60
T_9	Hydrochloric acid 0.1 N 0.5 % (HCl)	1.5	45
T_{10}	”	”	60
T_{11}	”	3	45
T_{12}	”	”	60
T_{13}	Hydrochloric acid 0.3 N 0.5 %	1.5	45
T_{14}	”	”	60
T_{15}	”	3	45
T_{16}	”	”	60
T_{17}	Sodium hexa meta phosphate (1.2 g per 100 g of sample)	400 ml per 100 g	60

Design : CRD

No. of replications :3

3.2.1 Quantity of pectin extract

The quantity of pectin extract obtained from different wastes due to varying treatments (as specified above) was measured separately. The content of pectin in each sample of extract was judged using two different methods suggested by Ranganna (1986).

(i) By examining the nature of pectin clot

(ii) By taking direct weight

3.2.2 Clot test for pectin

Ethanol (15ml) was added through the sides of beaker containing 5ml of pectin extract. The mixture was shaken well and kept for few minutes for clotting the pectin. The clot appeared in the beaker was graded as lumpsome, fragmented and granular, denoting their nature (Ranganna, 1986). Accordingly the material was categorised as those containing rich, medium and poor pectin. The nature of clot in three samples were examined under each treatment.

3.2.3 Direct weighing method

Pectin was precipitated by pouring ethanol three times to the volume of the extract through the sides of the beaker into the weighed cooled pectin extract. The mixture was shaken well and kept for few minutes and then filtered on coarse mesh nylon cloth. The pectin obtained was washed with ethanol containing 0.5M hydrochloric acid (pH should be between 0.7 and 1.0) and with 70 per cent alcohol. Then dehydration of pectin was done with a stream of dry air. After that, it was oven dried. The dried material was powdered using a mortar and pestle and weighed (g per 100ml of pectin extract). Three such samples were prepared under each treatments to examine the dry pectin content. Quantity of dried pectin obtained from each sample was calculated in percentage.

The pectin powder thus obtained was kept in small glass containers, sealed and stored airtight for further study.

3.3 Screening efficient method for pectin extraction

Based on the nature of clot and quantity of pectin recovered from different fruit wastes, each method of extraction was scored for their efficiency to extract pectin.

The method gave dry pectin above 10g per 100ml of pectin extract was assigned a score of 3, between 5 to 10 was assigned a score of 2 and below 5 was given a score of 1.

Similarly the method which produced lumpsome clot (rich pectin content) was assigned a score of 3, fragmented (medium pectin content) was assigned a score of 2 and granular (poor pectin content) was assigned a score of 1.

The differential effect of the treatments based on the nature of clot and percentage recovery of dry pectin were analysed individually, assigning total score value statistically by adopting Kruskal-Wallis One Way Analysis Of Variance (Siegel, 1956).

Based on the score value, the treatments were assessed for their efficiency for extracting pectin from different fruit wastes. For a material, the treatment which gained high score value was selected as the efficient method.

3.3.1 Identification of efficient citric acid treatments

Since pectin extracts obtained using citric acid treatments can be directly used for jelly preparation, the efficient citric acid treatment to extract maximum pectin was selected. The selection was made based on score value as well as the quantity of pectin extract obtained. For each fruit waste, the treatment which gained high score value for clot nature and dry pectin content as well as yielded high quantity of pectin extract (for citric acid treatment) was selected as the most ideal.

3.4 Quantity of pectin in different fruit wastes

The pectin content in each fruit waste was calculated by taking the average of the dry pectin obtained through the most efficient treatment identified for every fruit waste based on clot nature and dry pectin content.

3.5 Characterisation of pectin

The pectin obtained from different fruit wastes through the most efficient method identified were characterised by finding out their Anhydrogalacturonic acid percentage (AUA %), Methoxyl content (%), Gel grade and Acetyl value (%), adopting the standard methods suggested by Ranganna (1986).

3.5.1 Anhydrogalacturonic acid percentage (AUA%)

Making use of the equivalent weight, methoxyl content and the alkalinity of the ash data, the anhydrouronic acid was calculated from the expression given below:

$$\text{AUA\%} = \frac{176(\text{m.e. Alkali for free acid} + \text{m.e. Alkali for saponification} + \text{m.e. Titrable ash})}{\text{Weight of sample (mg)}} \times 100$$

where m.e. = milli equivalents

Equivalent weight determination method

A sample consisting of 0.50 g of pectic substance was moistened with 5ml ethanol. Added one gram of sodium chloride to sharpen the end point, followed by 100 ml of carbon dioxide – free distilled water and six drops of phenol red indicator. Titrated slowly (to avoid possible de -esterification) with 0.1 N NaOH until the colour change of the indicator persisted for more than 30 sec.

The neutralised solution was used for methoxyl determination

$$\text{Equivalent weight} = \frac{\text{Weight of sample} \times 1000}{\text{ml of alkali} \times \text{Normality of alkali}}$$

Alkalinity of the ash

A sample consisting of 0.50 g of pectic substance in a tared crucible was heated for 3to 4 hours at 600°C. The crucible was then cooled in a desiccator and weighed. To determine the alkalinity of the ash, dissolved the ash in 25 ml of 0.1N HCl. Heated gently to boiling and cooled. Titrated with 0.1N NaOH using phenolphthalein indicator (The normality of HCl and NaOH should be the same).

$$\text{Alkalinity (\%) as carbonate} = \frac{\text{Titre} \times \text{Normality of NaOH} \times 60 \times 100}{\text{Weight of ash} \times 1000}$$

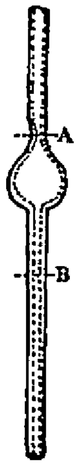
3.5.2 Methoxyl content

To the neutral solution titrated for equivalent weight, containing 0.50 g of pectic substance, added 25 ml of 0.2 N sodium hydroxide, shaken thoroughly and allowed to stand for 30 minutes at room temperature in a stoppered flask. Added 25 ml of 0.2 N HCl (or an amount equivalent to the base added) and titrated with 0.1 N NaOH to the same end point as before.

$$\text{Methoxyl content \%} = \frac{\text{ml of Alkali} \times \text{Normality of alkali} \times 3.1}{\text{Weight of sample}}$$

3.5.3 Gel grade

The pectin extract at room temperature is drawn up through the capillary into the bulb above the constriction marked A of jelmeter. Noted the time in seconds for the liquid to flow back of its own free will, from mark A to mark B when the apparatus is held upright. Washed the apparatus thoroughly and noted the time required for water of same temperature to flow between the same marks.



Ostwald's jelmeter (viscosity pipette)

$$\text{Relative viscosity at temperature T} = \frac{\text{Time in seconds for the extract to flow through}}{\text{Time in seconds for the water to flow through}}$$

Using this relative viscosity, gel grade was determined with the help of standard graph prescribed by Ranganna (1986).

3.5.4 Acetyl value

Weighed 0.50g of pectin and added 25ml of 0.1N NaOH. Stirred the contents until the pectin is dissolved and set aside overnight. Then diluted the contents to 50ml with water. Pipetted 20ml into the distillation apparatus. Added 20ml of magnesium sulphate – Sulphuric acid solution to it. Steam distilled and collected about 100 ml of distillate, keeping the volume in the distillation flask low. Titrated the acetic acid with 0.05 N sodium hydroxide to a phenol red end point.

$$\text{Acetyl value} = \frac{\text{Normality of NaOH} \times \text{Titre value (ml of NaOH)} \times 4.3}{\text{Weight of sample in aliquot (g)}}$$

3.6 Preparation of jelly and their quality evaluation

Jelly was prepared using different pectin extracts obtained through most efficient extraction methods identified for each sample (fruit waste). Equal quantity of pectin extract and sugar was taken and to that added citric acid at the rate of 5 g per kg of the pectin extract. The mixture was cooked in low flame until the mass achieved a jelly consistency or attained 72°Bx. The jellies prepared like this were evaluated for their qualities by visual means as well as organoleptically, with the help of a semi trained panel. The qualities of different jellies were compared with that of guava jelly, which was taken as the standard.

3.6.1 Visual judgement

3.6.1.1 Setting property

Time taken for setting : Recorded as the time taken by the jelly for attaining a proper set of required consistency after pouring in glass jars.

3.6.1.2 Consistency

Every jelly was examined for their consistency after setting viz., gel, firm and syrupy.

3.6.1.3 Syneresis or weeping jelly

The bottle in which the jelly kept was tilted and examined for separation of water from it. The jelly in which separation of water noticed was denoted as weeping jelly.

3.6.1.4 Colour

The colour of each jelly was examined by comparing with that of standard guava jelly.

3.6.1.5 Formation of crystals

The jelly was examined for the presence of crystals if any, for the period of storage for three months.

3.6.1.6 Cloudiness

Cloudiness was determined by comparing with the clarity of guava jelly. Those jellies which were not transparent was denoted as cloudy jelly.

The different jellies whose quality did not come to the standard of guava jelly when prepared by adopting the usual method (3.6) were selected out as a separate category. These were given different treatments for quality upgradation, to overcome their defects.

3.6.2 Organoleptic evaluation of jelly with the help of trained panel

A panel consisting of ten semi trained persons were served with the jelly samples for organoleptic evaluation. The characters analysed were appearance, transparency, colour, consistency, taste, aroma, flavour and acceptability as bread-spread.

The proforma used for this sensory evaluation is given in Appendix 1

Each character was evaluated for different jellies by assigning score value as follows.

Very good	5
Good	4
Fair	3
Satisfactory	2
Poor	1

For each character, average of the score value (given by the ten semi trained judges) was calculated. The jellies were assigned different characters based on their score acquisition as given below.

Very good	4.1 to 5.0
Good	3.1 to 4.0
Fair	2.1 to 3.0
Satisfactory	1.1 to 2.0
Poor	<1

3.7 Upgradation of jelly quality through special treatments

Based on the results of quality evaluation of jelly prepared from different fruit wastes (as given in 3.6.1 and 3.6.2), special treatments/method of preparation were tried for the following fruit wastes to improve their quality by correcting the defects identified.

Fruit waste	Special treatments tried	Purpose
Pineapple peel	Blended the pineapple peel pectin extract with pectin extracts prepared from different fruit wastes viz., mango peel and passion fruit rind at 1:1 ratio.	Removal of syrupy consistency
Banana peel	i) The peel was taken after scrubbing off the pulpy portion from the peel ii) The extraction time was reduced to 25 minutes from 45 and 60 minutes	Removal of cloudiness
Pumello peel	i) The chopped peel boiled in 1,2,3,4 and 6 % sodium chloride for 30 minutes and thoroughly washed with water before pectin extraction. ii) Dipped the chopped peel in lime at 2,4 and 6% for five hours and washed thoroughly with water before pectin extraction iii) Chopped peel boiled with sodium hydroxide at 0.175, 0.25, 0.5, 0.75, 1, 1.5 and 1.75% for 30 minutes and thoroughly washed with water before extracting pectin	De-bittering of pectin
	iv) Blended with pineapple peel pectin extract at the ratio of 1:1	To obtain gel consistency

Lime peel	Lime peel was treated with 1,2 and 3% sodium chloride by boiling for 30 minutes and kept overnight. Before extracting pectin, thorough washing was given.	De-bittering of pectin
Passion fruit rind	i) Jelly was prepared using reduced quantities of sugar viz., pectin extract and sugar in the ratio 1:0.75 ii) Blended with that of pineapple peel pectin extract at 1:1 ratio	Removal of crystals To obtain gel consistency
Cocoa pod husk	Jelly was prepared by blending cocoa pod husk pectin extract with that of mango peel pectin extract at 1:1ratio.	Removal of syrupy consistency and syneresis
Mangosteen rind	Jelly was prepared by blending mangosteen rind pectin extract with that of mango peel pectin extract at 1:1ratio.	Removal of syrupy consistency and syneresis

3.8 Evaluation of jelly quality under storage

The jelly prepared from different fruit wastes after rectifying the defects if any, were stored for three months in glass jars and evaluated at monthly intervals for their qualities as given above (3.6.1 and 3.6.2).

The major defects noticed during the storage period were taken care of and improvement in quality was attempted by giving various treatments as follows.

Fruit waste.	Special treatments given	Purpose
Mango peel	Jelly was prepared using reduced quantities of sugar viz., pectin extract and sugar at the ratio of 1:05 and 1:0.75	Removal of crystals
Banana peel	Jelly was prepared using reduced quantities of sugar viz., pectin extract and sugar at the ratio of 1:0.5 and 1: 0.75	Removal of crystals
Passion fruit rind	Jelly was prepared using reduced quantities of sugar viz., pectin extract and sugar at the ratio of 1:0.5 and 1: 0.75	Removal of crystals

The efficiency of different treatments given for improving the quality of different jellies were evaluated through quality evaluation as described in 3.6.1 and 3.6.2.

Results

RESULTS

The data and observations of the present study on "Evaluation of fruit wastes as sources of pectin" were analysed and the results are presented in this chapter.

The recovery of wastes from different fruits, methods for pectin extraction, quantity of pectin content in different fruit wastes, characters of pectin obtained from different fruit wastes and quality of jelly prepared out of pectin extracts from different fruit wastes were analysed in the present investigation.

4.1 Recovery of wastes from different fruits

The waste material of different fruits (mango, jackfruit, pineapple, banana, nutmeg, pumello, passionfruit, cocoa, lime and mangosteen etc.), that can be used for pectin extraction, and the percentage recovery of such wastes are presented in Table 1.

It can be seen from the Table that above 25 percentage of the weight of different fruits analysed is contributed either by their peel, rind or husk, which are being wasted.

For nutmeg fruit, 82 percentage of its weight is constituted by rind. Similarly 80.69 percentage of the weight of a cocoa pod is contributed by its husk. Eventhough mango and banana produce less quantity of waste (peel) it also comes to 27.67 and 29.67 per cent respectively.

Table 1. Recovery of waste materials from different fruits for pectin extraction.

Fruit	Waste portion	Recovery (%)
Mango	Peel	27.67
Jackfruit	Rind	59.00
Pineapple	Peel	47.00
Banana	Peel	29.67
Nutmeg	Rind	82.00
Pumello	Peel	49.67
Passion fruit	Rind	49.00
Cocoa	Pod husk	80.69
Lime	Peel	50.00
Mangosteen	Rind	71.33
Mean		54.60
CD ($p<0.05$)		2.83
SE±		1.40

4.2 Efficiency of different methods for pectin extraction

The efficiency of different treatments as given under (3.2) for extracting pectin were analysed based on recovery of pectin extract (Plate 2), nature of pectin clot and dry pectin content. The results are given in Table 2.

4.2.1 Quantity of pectin extract

The quantity of pectin extract obtained varied with respect to time of extraction and quantity of water added to the material. Thus for all samples, the quantity of pectin extract obtained was significantly high for T_{17} (extraction with sodium hexa meta phosphate (1.2g per 100g of sample) and water (400ml) and boiling for 60 minutes).

There was no significant variation in the quantity of pectin extract when citric acid and hydrochloric acid were used at different concentrations and extraction was carried out by adding water at the ratio 1:1.5 (sample:water) and boiled for 45 and 60 minutes intervals.

When water was added to the sample at the ratio of 1:3, the treatments T_3 and T_{11} gave significantly high quantity of pectin extract (2410.33 and 2521g per kg of waste material respectively) for mango peel. Similarly, T_3 and T_{15} for jackfruit and passion fruit rind, T_3 , T_4 and T_7 for pineapple and banana peel, T_7, T_{11} and T_{15} for nutmeg rind, T_3 , T_4, T_7, T_{11} and T_{15} for pumello peel, T_3 , T_4, T_7, T_{11}, T_{12}, T_{15} and T_{16} for cocoa pod husk, T_3 , T_7, T_8, T_{11} and T_{15} for lime peel and T_3 , T_7, T_{15} and T_{16} for mangosteen rind produced significantly high quantity of pectin extract.

Plate 2. Pectin extract from different fruit wastes

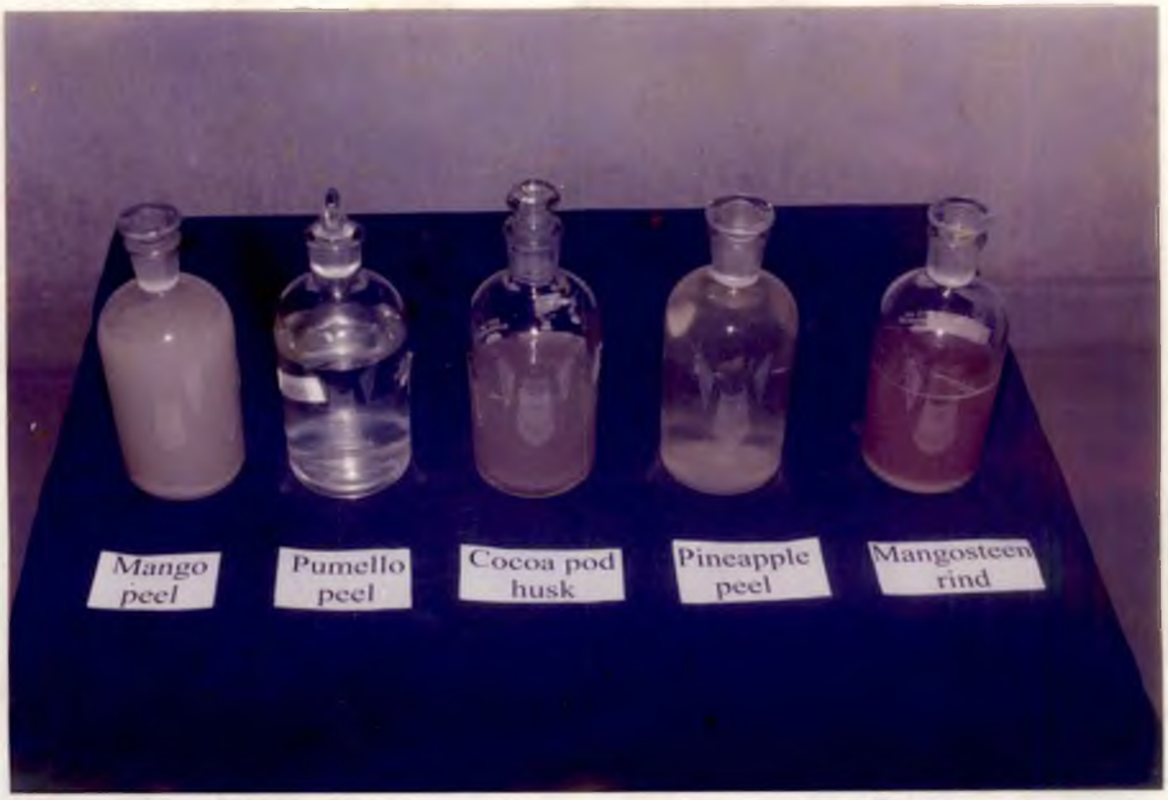


Table 2. Effect of method of extraction on amount of pectin extract, nature of pectin clot and dry pectin content of fruit wastes.

Fruit waste	Treatment	Amount of pectin extract (per kg of waste material) (g)	Nature of pectin clot	Dry pectin content (%) (per 100ml of pectin extract)
Mango peel	T_1	916.67	F	3.12
	T_2	898.00	L	5.55
	T_3	2410.33	L	6.15
	T_4	2134.00	L	5.71
	T_5	925.17	L	5.64
	T_6	896.00	L	6.00
	T_7	2223.30	L	5.78
	T_8	2009.28	L	6.36
	T_9	928.33	F	2.89
	T_{10}	910.00	L	6.22
	T_{11}	2521.00	L	6.39
	T_{12}	2258.30	F	3.06
	T_{13}	910.00	L	6.18
	T_{14}	886.00	L	6.50
	T_{15}	2083.33	F	2.90
	T_{16}	1916.29	L	6.30
	T_{17}	3566.78	G	2.21
Mean		1674.02		5.12
CD ($p<0.05$)		114.10		0.32
SE±		39.86		0.11
Jack fruit	T_1	935.00	F	3.52
	T_2	904.30	F	3.6
	T_3	2522.67	G	2.68
	T_4	2357.60	G	2.76
	T_5	932.67	L	8.18
	T_6	912.00	L	6.9
	T_7	2316.57	G	2.87
	T_8	2135.00	G	3.00
	T_9	932.68	F	3.76
	T_{10}	908.00	F	3.42
	T_{11}	2320.58	G	2.6
	T_{12}	2220.30	G	2.55
	T_{13}	923.00	L	7.33

Table 2 contd...

	T_{14}	901.00	L	7.95
	T_{15}	2498.00	F	3.75
	T_{16}	2294.33	F	3.73
	T_{17}	3536.57	F	3.51
Mean		1732.64		4.24
CD		133.51		0.23
SE±		46.52		0.08
Pineapple peel	T_1	922.30	G	-
	T_2	905.46	G	-
	T_3	2466.63	G	-
	T_4	2312.00	G	-
	T_5	915.33	F	-
	T_6	894.30	G	-
	T_7	2339.00	G	-
	T_8	2172.30	G	-
	T_9	922.00	G	-
	T_{10}	897.67	G	-
	T_{11}	2200.00	G	-
	T_{12}	1918.00	G	-
	T_{13}	942.67	F	-
	T_{14}	917.00	G	-
	T_{15}	2169.33	G	-
	T_{16}	1886.66	G	-
	T_{17}	3533.34	G	-
Mean		1661.96		
CD		220.44		
SE±		76.81		
Banana peel	T_1	917.33	F	2.64
	T_2	894.67	F	2.63
	T_3	2296.29	G	1.70
	T_4	2101.58	G	2.00
	T_5	920.63	G	1.79
	T_6	890.62	L	3.49
	T_7	2177.66	G	1.71
	T_8	1934.67	G	1.92
	T_9	919.67	F	2.33
	T_{10}	892.30	F	2.55
	T_{11}	1967.62	G	1.69
	T_{12}	1758.00	F	2.39

Table 2 contd...

	T_{13}	936.32	L	3.51
	T_{14}	908.30	L	3.53
	T_{15}	2085.28	G	1.42
	T_{16}	1831.00	F	2.57
	T_{17}	3566.62	G	1.10
Mean		1588.04		2.29
CD		206.55		0.14
SE±		71.97		0.05
Nutmeg rind	T_1	922.00	L	3.99
	T_2	899.66	F	3.72
	T_3	1920.00	G	1.96
	T_4	1729.00	F	3.78
	T_5	916.67	L	4.14
	T_6	887.66	G	2.04
	T_7	2193.33	F	3.28
	T_8	2056.00	G	2.24
	T_9	920.67	F	3.49
	T_{10}	897.33	L	4.17
	T_{11}	2239.69	F	3.11
	T_{12}	2076.34	L	4.22
	T_{13}	914.67	L	4.14
	T_{14}	888.64	L	4.16
	T_{15}	2155.68	F	3.34
	T_{16}	1937.00	F	3.46
	T_{17}	3483.38	F	3.15
Mean		1562.94		3.44
CD		122.78		0.17
SE±		42.78		0.06
Pumello peel	T_1	918.00	L	3.54
	T_2	889.67	F	2.14
	T_3	2274.66	F	2.13
	T_4	2100.00	G	1.06
	T_5	926.66	G	1.08
	T_6	900.67	F	2.02
	T_7	2312.00	G	1.15
	T_8	2081.60	G	1.08
	T_9	904.33	L	3.69
	T_{10}	878.30	F	2.22
	T_{11}	2269.67	F	2.21

Table 2 contd...

	T_{12}	2061.00	G	1.03
	T_{13}	916.66	F	2.16
	T_{14}	887.34	F	2.09
	T_{15}	2289.33	F	2.02
	T_{16}	2028.33	G	1.34
	T_{17}	3566.66	L	3.71
Mean		1659.22		2.04
CD		227.76		0.11
SE±		79.36		004
Passion fruit rind	T_1	927.00	L	16.17
	T_2	900.67	L	15.86
	T_3	2275.66	L	15.66
	T_4	1960.67	L	15.94
	T_5	913.33	L	14.60
	T_6	880.00	G	6.40
	T_7	2092.00	L	16.23
	T_8	1819.00	F	8.67
	T_9	913.33	F	7.91
	T_{10}	880.67	G	5.36
	T_{11}	1861.66	F	8.61
	T_{12}	1702.00	F	8.84
	T_{13}	919.34	L	15.79
	T_{14}	891.67	G	5.83
	T_{15}	2238.00	F	8.17
	T_{16}	1999.33	L	15.99
	T_{17}	3426.63	F	8.56
Mean		1566.28		11.45
CD		162.76		0.86
SE±		56.71		0.30
Cocoa pod husk	T_1	932.66	G	2.30
	T_2	907.00	G	2.24
	T_3	2350.00	G	2.34
	T_4	2127.33	F	3.34
	T_5	929.00	G	2.25
	T_6	901.67	F	3.17
	T_7	2434.00	G	2.47
	T_8	1869.66	F	3.45
	T_9	908.34	L	3.68
	T_{10}	863.00	L	3.88

Table 2 contd...

	T_{11}	2494.60	G	2.25
	T_{12}	2313.68	F	3.28
	T_{13}	939.29	L	4.09
	T_{14}	908.00	F	3.08
	T_{15}	2292.00	F	3.12
	T_{16}	2102.33	L	3.96
	T_{17}	3600.43	F	3.46
Mean		1602.20		3.08
CD		642.54		0.14
SE±		223.88		0.05
Lime peel	T_1	927.00	L	11.60
	T_2	893.00	G	3.98
	T_3	2334.67	L	11.07
	T_4	2179.00	L	11.61
	T_5	930.00	L	11.27
	T_6	898.66	L	11.83
	T_7	2491.00	F	5.48
	T_8	2313.00	L	11.17
	T_9	951.00	G	4.39
	T_{10}	917.67	F	6.21
	T_{11}	2356.33	G	3.36
	T_{12}	2175.30	G	3.49
	T_{13}	934.38	F	6.25
	T_{14}	889.64	G	3.62
	T_{15}	2438.67	G	4.42
	T_{16}	2266.00	G	3.54
	T_{17}	3566.36	F	5.72
Mean		1737.94		7.00
CD		197.6		0.69
SE±		68.85		0.24
Mangosteen rind	T_1	943.33	G	1.65
	T_2	830.30	G	1.29
	T_3	2244.00	G	1.63
	T_4	2088.66	G	1.66
	T_5	897.33	G	1.83
	T_6	771.32	F	2.43
	T_7	2191.00	F	2.28
	T_8	1973.67	F	2.39
	T_9	912.69	L	3.60

Table 2 contd...

	T_{10}	810.33	L	3.58
	T_{11}	2029.00	L	3.58
	T_{12}	1745.67	G	1.64
	T_{15}	2545.67	G	1.97
	T_{13}	938.00	G	1.66
	T_{14}	808.00	G	1.72
	T_{16}	2384.00	G	2.01
	T_{17}	3733.34	F	3.28
Mean		1631.96		2.25
CD		447.40		0.32
SE±		155.89		0.11

L : Lumpsome F : Fragmented G : Granular

4.2.2 Nature of clot

The nature of clot examined by precipitating pectin from pectin extracts of different samples using ethanol is presented in Table 2.

When precipitation was carried out from mango peel pectin extract, the treatments except T_1,T_9,T_{12} and T_{15} proved their superiority by producing lumpsome clot. Similarly, lumpsome clot of pectin was produced by treatments T_5, T_6, T_{13} and T_{14} of jackfruit rind, T_6, T_{13} and T_{14} of banana peel, T_1, T_5, T_{10}, T_{12}, T_{13} and T_{14} of nutmeg rind, T_1, T_9 and T_{17} of pumello peel, T_1, T_2, T_3, T_4, T_5, T_7, T_{13} and T_{16} of passion fruit rind, T_9, T_{10}, T_{13} and T_{16} of cocoa pod husk, T_1, T_3, T_4, T_5, T_6, and T_8 of lime peel and T_9, T_{10} and T_{11} of mangosteen rind.

The other treatments provided only fragmented or granular clots, which are considered to be less efficient methods.

No lumpsome clot was found with pineapple peel pectin extract. For this, fragmented clot was obtained with treatments T_5 and T_{13}. For all other treatments, the clot obtained was granular.

4.2.3 Dry pectin content

The percentage recovery of dry pectin from the extract of different fruit wastes are also presented in Table 2.

From the Table, it can be seen that the treatments T_8, T_{11}, T_{14}, and T_{16} were more efficient in extracting pectin from mango peels. The dry pectin content was significantly high (6.3 to 6.5%) in these treatments. Similarly the treatments T_{14} was better for extracting pectin (dry pectin recovery was 7.95%) of jackfruit rind, T_6, T_{13}

and T_{14} of banana peel (dry pectin recovery ranged from 3.49% to 3.53%), T_1,T_5, T_{10}, T_{12}, T_{13} and T_{14} (dry pectin recovery is in the range of 3.99% to 4.22%) of nutmeg rind, T_9 and T_{17} (dry pectin recovery ranged from 3.69% to 3.71%) of pumello peel, T_1, T_2, T_3, T_4, T_7, T_{13} and T_{16} of passion fruit rind (dry pectin recovery ranged from 15.66% to 16. 23%), T_{13} and T_{16} of cocoa pod husk (dry pectin recovery was in the range of 3.96% to 4.09%), T_1, T_4, T_5, T_6 and T_8 (dry pectin recovery ranged from 11.17% to 11.83%) of lime peel and T_9, T_{10}, T_{11} and T_{17} of mangosteen rind (dry pectin recovery ranged between 3.28% and 3.6%) were found to be better for pectin extraction.

All other treatments were ranked inferior in the dry pectin recovery.

Dry pectin content of pineapple peel extract was not enough to quantify the recovery.

4.3 Selection of efficient method for pectin extraction through scoring technique

The score gained by different treatments based on Kruskal-Wallis One-Way Analysis Of Variance (3.3) is given in Table 3.

The score value of the treatments except for T_1, T_9, T_{12} and T_{15} imposed for extracting pectin from mango peels were significantly high compared to other treatments. The treatments T_5, T_6, T_{13} and T_{14} of jack fruit rind samples had significantly high score value (136.5). Likewise, the treatments T_6 and T_{14} of banana peel (138), T_1, T_5, T_{10}, T_{13}, and T_{14} of nutmeg rind (124), T_9 of pumello peel and cocoa pod husk (138 and 140 respectively), T_1, T_2, T_3, T_4, T_7, T_{13} and T_{16} of passion fruit rind (121.5), T_1, T_3, T_4, T_5 and T_6 of lime peel (129) and T_9 and T_{11} of mangosteen rind (140.5) were found efficient and acquired high score values when compared to other treatments.

Table 3. Score value for different methods of pectin extraction for each fruit waste based on nature of clot and percentage recovery of dry pectin. (The total given is that obtained through Kruskal-Wallis One-Way Analysis Of Variance).

Fruit waste	Treatments	Average score value		Total score value
		Based on nature of clot	Based on percentage recovery	
Mango peel	T_1	2	1	19
	T_2	3	2	99.5
	T_3	3	2	99.5
	T_4	3	2	99.5
	T_5	3	2	99.5
	T_6	3	2	99.5
	T_7	3	2	99.5
	T_8	3	2	99.5
	T_9	2	1	37.5
	T_{10}	3	2	99.5
	T_{11}	3	2	99.5
	T_{12}	2	1	25.5
	T_{13}	3	2	99.5
	T_{14}	3	2	99.5
	T_{15}	2	1	37.5
	T_{16}	3	2	99.5
	T_{17}	1	1	12.5
				$\chi^2 = 26.3$
Jack fruit rind	T_1	2	1	82.5
	T_2	2	1	82.5
	T_3	1	1	36
	T_4	1	1	36
	T_5	3	2	136.5
	T_6	3	2	136.5
	T_7	1	1	36

Table 3 contd...

	T_8	1	1	36
	T_9	2	1	82.5
	T_{10}	2	1	82.5
	T_{11}	1	1	36
	T_{12}	1	1	36
	T_{13}	3	2	136.5
	T_{14}	3	2	136.5
	T_{15}	2	1	82.5
	T_{16}	2	1	69
	T_{17}	2	1	82.5
Banana peel	T_1	2	1	100
	T_2	2	1	100
	T_3	1	1	46
	T_4	1	1	46
	T_5	1	1	46
	T_6	3	1	138
	T_7	1	1	46
	T_8	1	1	46
	T_9	2	1	84
	T_{10}	2	1	100
	T_{11}	1	1	46
	T_{12}	2	1	100
	T_{13}	3	1	138
	T_{14}	3	1	138
	T_{15}	1	1	27
	T_{16}	2	1	100
	T_{17}	1	1	46
Nutmeg rind	T_1	3	1	124
	T_2	2	1	73.5
	T_3	1	1	12
	T_4	2	1	73.5
	T_5	3	1	124
	T_6	1	1	26
	T_7	2	1	54
	T_8	1	1	26
	T_9	2	1	54
	T_{10}	3	1	124
	T_{11}	2	1	73.5
	T_{12}	3	1	124

Table 3 contd...

	T_{13}	3	1	124
	T_{14}	3	1	124
	T_{15}	2	1	54
	T_{16}	2	1	73.5
	T_{17}	2	1	73.5
Pumello peel	T_1	3	1	132
	T_2	2	1	95
	T_3	2	1	95
	T_4	1	1	24
	T_5	1	1	41.5
	T_6	2	1	76.5
	T_7	1	1	41.5
	T_8	1	1	41.5
	T_9	3	1	138
	T_{10}	2	1	95
	T_{11}	2	1	76.5
	T_{12}	1	1	41.5
	T_{13}	2	1	76.5
	T_{14}	2	1	95
	T_{15}	2	1	95
	T_{16}	1	1	41.5
	T_{17}	3	1	132
Passion fruit rind	T_1	3	3	121.5
	T_2	3	3	121.5
	T_3	3	3	121.5
	T_4	3	3	121.5
	T_5	3	3	90.5
	T_6	1	2	17.5
	T_7	3	3	121.5
	T_8	2	2	50
	T_9	2	2	63
	T_{10}	1	2	17.5
	T_{11}	2	2	50
	T_{12}	2	2	37
	T_{13}	3	3	121.5
	T_{14}	1	2	37
	T_{15}	2	2	50
	T_{16}	3	3	121.5
	T_{17}	2	2	63

Table 3 contd...

Cocoa pod husk	T_1	1	1	42
	T_2	1	1	22.5
	T_3	1	1	42
	T_4	2	1	81
	T_5	1	1	42
	T_6	2	1	81
	T_7	1	1	42
	T_8	2	1	81
	T_9	3	1	140
	T_{10}	3	1	135
	T_{11}	1	1	22.5
	T_{12}	2	1	81
	T_{13}	3	1	135
	T_{14}	2	1	81
	T_{15}	2	1	81
	T_{16}	3	1	140
	T_{17}	2	1	81
Lime peel	T_1	3	3	129
	T_2	1	1	28.5
	T_3	3	3	129
	T_4.	3	3	129
	T_5	3	3	129
	T_6	3	3	129
	T_7	2	2	79.5
	T_8	3	3	129
	T_9	1	1	28.5
	T_{10}	2	2	79.5
	T_{11}	1	1	28.5
	T_{12}	1	1	40.5
	T_{13}	2	2	87
	T_{14}	1	1	40.5
	T_{15}	1	1	28.5
	T_{16}	1	1	40.5
	T_{17}	2	2	79.5
Mangosteen rind	T_1	1	1	39
	T_2	1	1	39
	T_3	1	1	59
	T_4	1	1	39
	T_5	1	1	59

Table 3 contd…

	T_6	2	1	111
	T_7	2	1	111
	T_8	2	1	99
	T_9	3	1	140.5
	T_{10}	3	1	140.5
	T_{11}	3	1	140.5
	T_{12}	1	1	39
	T_{13}	1	1	59
	T_{14}	1	1	59
	T_{15}	1	1	39
	T_{16}	1	1	59
	T_{17}	2	1	99

The treatments selected from different fruit waste samples are listed below.

Fruit waste	Treatments
Mango peel	T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_{10}, T_{11}, T_{13}, T_{14} and T_{16}
Jackfruit rind	T_5, T_6, T_{13} and T_{14}
Pineapple peel	None of the treatments given was effective
Banana peel	T_6, T_{13} and T_{14}
Nutmeg rind	T_1, T_5, T_{10}, T_{13} and T_{14}
Pumello peel	T_9
Passion fruit rind	T_1, T_2, T_3, T_4, T_7, T_{13} and T_{16}
Cocoa pod husk	T_9
Lime peel	T_1, T_3, T_4, T_5, T_6 and T_8
Mangosteen rind	T_9, T_{10} and T_{11}

4.3.1 Efficient citric acid treatment for pectin extraction

The best citric acid treatment selected for each fruit waste based on the clot nature, dry pectin content and quantity of pectin extract obtained is given below.

Fruit waste	Treatments
Mango peel	(i) Boiling with citric acid 0.75% and water (three times) for 60 minutes (T_8)
Jackfruit rind	(i) Boiling with citric acid 0.75% and water (1.5 times) for 45 minutes (T_5)
Banana peel	(i) Boiling with citric acid 0.75% and water (1.5 times) for 60 minutes (T_6)
Nutmeg rind	(i) Boiling with citric acid 0.75% and water (1.5 times) for 45 minutes (T_5)
Pumello peel	(i) Boiling with citric acid 0.5% and water (1.5 times) for 45 minutes (T_1)
Passion fruit rind	(i) Boiling with citric acid 0.75% and water (three times) for 45 minutes (T_7)
Cocoa pod husk	-
Lime peel	(i) Boiling with citric acid 0.5% and water (three times) for 60 minutes (T_4)
Mangosteen rind	-

For mangosteen rind and cocoa pod husk, no lumpsome clot was obtained for citric acid treatments. Quantity of dry pectin obtained from such extracts was also low.

4.4 Quantification of pectin in different fruit wastes

The quantity of pectin in different fruit wastes are given in Table 4.

Highest pectin recovery was obtained from passion fruit rind (252.68 g per kg), followed by lime peel (180.48 g per kg). Lowest recovery was from banana peel (32 .08 g per kg). Pumello peel and cocoa pod husk also gave less amount of pectin (33.36 and 32.62 g per kg respectively). Pectin was not recovered from pineapple peel.

4.5 Characters of pectin from different fruit wastes

The data on characteristics of pectin analysed viz., anhydro uronic acid (%), methoxyl content (%), gel grade and acetyl value are presented in Table 5.

4.5.1 Anhydro uronic acid (AUA(%))

The AUA(%) was significantly high in the pectin samples of mangosteen rind and lime peel (73.16 and 72.5 respectively). Passion fruit rind pectin had the least value (46.17) for AUA(%).

4.5.2 Methoxyl content (%)

The methoxyl content ranged from 4.96 to 10.54 per cent for different samples. Highest methoxyl content was for mangosteen rind pectin (10.54 %), whereas passion fruit rind pectin had the lowest (4.96 %).

4.5.3 Gel grade

Highest gel grade was obtained for lime peel pectin (213) followed with pumello peel (202) and mango peel (199). The lowest gel grade was for passion fruit rind pectin (73). For other samples, the gel grade ranged from 100 to 171.

Table 4. Yield of dry pectin from fruit wastes

Fruit waste	Quantity (g per kg of fruit waste)
Mango peel	95.10
Jack fruit rind	69.27
Pineapple peel	-
Banana peel	32.08
Nutmeg rind	37.23
Pumello peel	33.36
Passion fruit rind	252.68
Cocoa pod husk	32.62
Lime peel	180.48
Mangosteen rind	42.83
Mean	86.18
CD ($p<0.05$)	1.49
SE±	0.52

Table 5. Variability in AUA, methoxyl content, gel-grade and acetyl value of pectin extracted from fruit wastes

Fruit waste used for pectin extraction	AUA(%)	Methoxyl content (%)	Gel grade	Acetyl value (%)
Mango peel	56.67	7.33	199	-
Jackfruit rind	66.00	7.67	159	-
Pineapple peel	-	-	-	-
Banana peel	53.00	7.03	99	-
Nutmeg rind	59.50	7.49	167	-
Pumello peel	64.17	8.57	202	-
Passion fruit rind	46.17	4.96	73	-
Cocoa pod husk	52.84	6.97	129	1.2
Lime peel	72.50	9.92	213	-
Mangosteen rind	73.16	10.54	171	-
Mean	60.45	7.94	157	-
CD ($p<0.05$)	0.82	0.39	4.28	-
SE±	0.41	0.19	1.49	-

AUA (%) – Anhydro Uronic Acid

4.5.4 Acetyl value (%)

It was found only in cocoa pod husk pectin (1.2 %).

4.6 Quality evaluation of jelly from different fruit wastes

4.6.1 Visual observations

The jellies prepared out of pectin extracts from different fruit wastes (Plate 3) were analysed for their setting property, consistency, syneresis, colour, crystallisation and cloudiness, in comparison with standard guava jelly. The data are presented in Table 6.

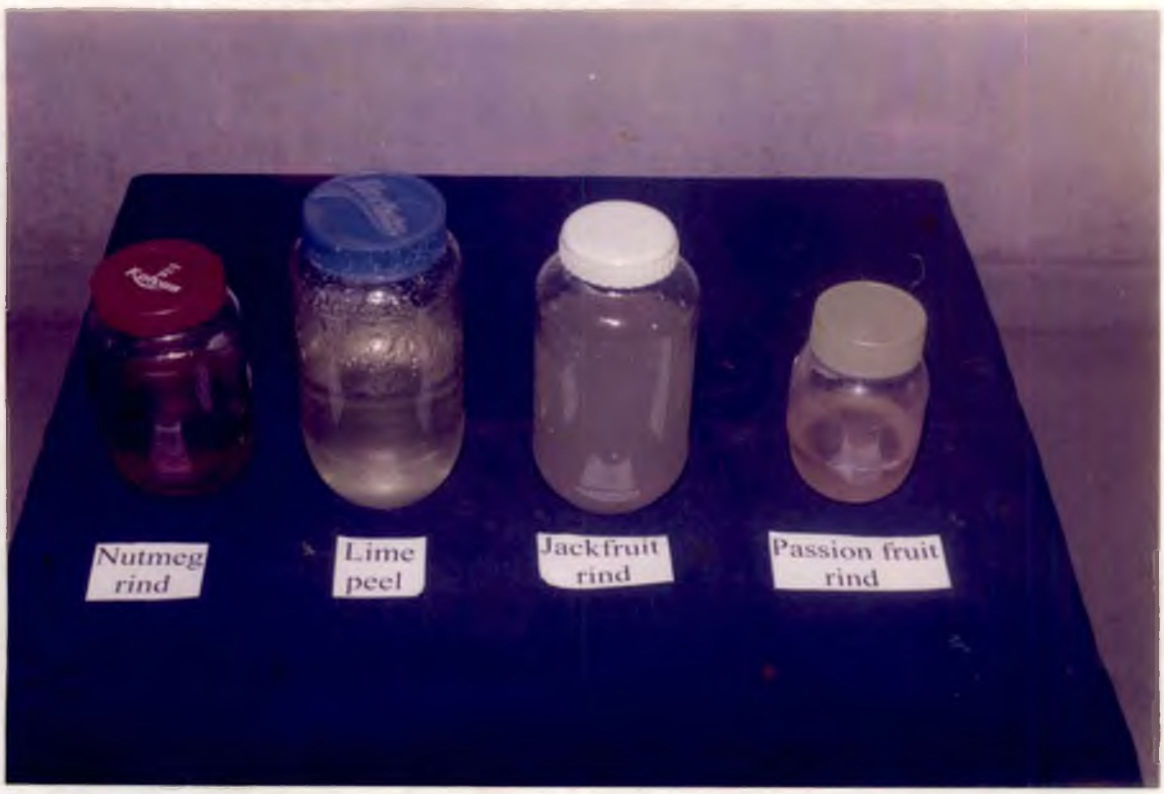
4.6.1.1 Rate of setting and setting time

Very fast setting viz., setting within 20 minutes was noted with jelly made from lime peel and passion fruit rind whereas pumello peel jelly took 1 hour for setting. The setting was moderately fast (setting within 2 to 3 hrs) with jelly prepared from mango peel, jackfruit rind, banana peel and nutmeg rind. Jellies from pineapple peel and cocoa pod husk pectin extract exhibited very slow setting.

4.6.1.2 Consistency

The desirable consistency viz., gel nature was obtained for jelly made from pectin extracts of mango peel, jackfruit rind, banana peel, nutmeg rind and lime peel. Jelly from pumello peel and passion fruit rind extracts were of firm consistency. The jelly from pineapple peel, cocoa pod husk and mangosteen rind extracts were of inferior consistency, which was denoted as syrupy.

Plate 3. Jelly prepared using extracts of different fruit wastes



Guava jelly
(Standard)

Table 6. Quality of jelly as influenced by source of pectin (visual observations).

Fruit wastes used for jelly preparation	Setting time	Rate of setting	Consistency	Syneresis	Colour	Crystallisation	Cloudiness
1. Mango peel	2 hrs.	Moderately fast	G	A	Golden yellow	A	A
2. Jackfruit rind	3 hrs.	Moderately fast	G	A	Pale yellow	A	A
3. Pineapple peel	No proper setting		S	P	Golden yellow	A	A
4. Banana peel	2 hrs.	Moderately fast	G	A	Yellowish brown	A	A
5. Nutmeg rind	2 hrs.	Moderately fast	G	A	Dark brown	A	A
6. Pumello peel	1 hr.	Fast	F	A	Pale yellow	A	A
7. Passion fruit rind	20 min.	Very fast	F	A	Pale yellow	A	A
8. Cocoa pod husk	Not proper setting		S	P	Pale yellow	A	A
9. Lime peel	20 min.	Very fast	G	A	Golden yellow	A	A
10. Mangosteen rind	No proper setting		S	P	Pink	A	A
Guava jelly (Standard)	1 hr.	Fast	G	A	Brown	A	A

Consistency

G : Gel F : Firm S : Syrupy
P : present A : Absent

4.6.1.3 Syneresis

Syneresis was observed only in jellies made from pineapple peel, cocoa pod husk and mangosteen rind.

4.6.1.4 Colour

The colour of most of the jellies ranged from pale yellow to golden yellow whereas jelly from nutmeg rind and banana peel were of dark brown and yellowish brown respectively. Jelly from mangosteen rind was of pink colour.

4.6.1.5 Presence of crystals

No crystallisation was noticed in any jelly.

4.6.1.6 Cloudiness

Cloudiness (loss of transparent nature) was observed only for banana peel jelly (Plate 4), whereas all other jellies were transparent.

4.6.2 Organoleptic evaluation of jelly prepared from fruit wastes immediately after preparation (after attaining proper set)

The jellies prepared from pectin extracts of fruit wastes were evaluated organoleptically for various criteria viz., appearance, transparency, colour, consistency, taste, aroma, flavour, off-flavour and acceptability as bread spread. The results of organoleptic evaluation are given in Table 7.

Plate 4. Cloudiness of banana peel jelly

Plate 5. Crystallisation in mango peel jelly

Table 7. Organoleptic quality of jelly as influenced by source of pectin (after attaining proper set)

Criteria	A	B	C	D	E	A_1	B_1	C_1	D_1	E_1
Appearance	Good	Very good	Good	Good	Fair	Good	Fair	Fair	Good	Good
Transparency	Fair	Very good	Very good	Good	Fair	Fair	Good	Fair	Good	Fair
Colour	Good	Very good	Good	Good	Fair	Good	Fair	Good	Good	Fair
Consistency	Fair	Fair	Good	Fair	Fair	Fair	Fair	Good	Fair	Good
Taste	Good	Good	Satisfactory	Good	Fair	Fair	Fair	Good	Good	Poor
Aroma	Good	Fair	Fair	Good	Good	Satisfactory	Fair	Fair	Good	Satisfactory
Fruity flavour	Ab	P	P	P	P	P	Ab	P	P	Ab
Off-flavour	Ab	Ab	P	Ab	Ab	Ab	Ab	Ab	Ab	P
Acceptability as bread-spread	Good	Good	Fair	Good	Good	Good	Fair	Fair	Good	Poor

A : Banana peel jelly A_1 : Mangosteen rind jelly
B : Nutmeg rind jelly B_1 : Cocoa pod husk jelly
C : Lime peel jelly C_1 : Passionfruit rind jelly
D : Mango peel jelly D_1 : Pineapple peel jelly
E : Jackfruit rind jelly E_1 : Pumello peel jelly
P : Present Ab : Absent

4.6.2.1 Appearance

The appearance of nutmeg rind jelly fell in the category "very good" whereas that of jellies made from banana peel, lime peel, mango peel, mangosteen rind, pineapple peel and pumello peel was rated as good. Jackfruit rind, cocoa pod husk and passion fruit rind jelly were ranked fair for 'appearance'. No jelly was rated 'poor'for 'appearance' by the panelists.

4.6.2.2 Transparency

Very good transparency was observed with nutmeg rind and lime peel jelly. Jellies made from mango peel, cocoa pod husk and pineapple peels were transparent and categorised as those having good transparency. The transparency was fair for jelly made from banana peel, jackfruit rind, mangosteen rind, passion fruit rind and pumello peel. No jelly was scored under poor transparency.

4.6.2.3 Colour

The colour of nutmeg rind jelly was found "very good", whereas the colour of jelly prepared using pectin extracts of banana peel, lime peel, mango peel, mangosteen rind, passion fruit rind and pineapple peel was scored "good". All other jellies were categorised as fair in colour, as per evaluation.

4.6.2.4 Consistency

Good consistency was seen in jelly prepared from lime peel, passion fruit rind and pumello peel pectin extract. Consistency of all other jellies was fair.

4.6.2.5 Taste

The taste of jelly from pineapple peel, banana peel, nutmeg rind, mango peel and passion fruit rind pectin extract was good. All other jellies except that of lime peel and pumello peel were scored under those having fair taste. The taste of lime peel jelly was satisfactory and the taste of pumello peel jelly was poor as per the organoleptic evaluation.

4.6.2.6 Aroma

The aroma of banana peel, pineapple peel, mango peel and jackfruit rind jellies was rated as 'good'. Pumello peel and mangosteen rind jelly gave satisfactory aroma, while the aroma of all other jellies was rated as ' fair'.

4.6.2.7 Fruity flavour

Fruity flavour was present in jellies made from nutmeg rind, lime peel, mango peel, jackfruit rind, mangosteen rind, passion fruit rind and pineapple peel. It was absent in other jellies.

Off-flavour was not found in any jelly except those made from pumello peel and lime peel pectin extracts.

4.6.2.8 Acceptability as bread-spread

The acceptability of jellies made from banana peel, nutmeg rind, jackfruit rind, pineapple peel, mango peel and mangosteen rind, as bread-spread was scored as "good". The acceptability of pumello peel jelly as bread -spread was found poor. All other jellies were fairly acceptable as bread-spread.

4.7 Quality improvement of jelly from different fruit wastes

The effect of treatments on quality improvement of jelly prepared from different fruit wastes are given in Table 8.

For removing the syrupy consistency of pineapple peel jelly, blending its pectin extract with that of passion fruit rind at the ratio of 1:1 was found very effective. Syrupy consistency and syneresis of cocoa pod husk and mangosteen rind jelly were removed by blending their pectin extracts with that of mango peel at the ratio 1:1.

Successful removal of cloudiness from banana peel was achieved by reducing the time of pectin extraction to 25 minutes from 45 and 60 minutes.

Complete de-bittering of pumello peel jelly was achieved by boiling the peels with six per cent sodium chloride for 30 minutes before pectin extraction, whereas de-bittering in lime peel was successful when the peels were boiled with three per cent sodium chloride for 30 minutes before extracting pectin.

The results obtained on the visual and organoleptic evaluation of jelly, soon after quality improvement is given in Appendix 2.

4.8 Quality variation in jellies under storage

Visual and organoleptic evaluations of jellies were carried out for three months, taking observation at monthly intervals.

4.8.1 Visual observations

Under visual observation, consistency, syneresis, colour, crystallisation and cloudiness were noted. The results are given in Table 9.

Table 8. Effect of corrective treatments on quality of jelly.

Jelly	Defect noticed	Corrective treatments carried out	Improvement in quality of jelly
Pineapple peel	Syrupy consistency	i. Blended with mango peel pectin extract at the ratio of 1:1	Syrupy consistency was reduced
		ii. Blended with passion fruit rind pectin extract at the ratio of 1:1	Gel consistency was obtained
Banana peel	Cloudiness	i. Scrubbed the peel to remove adhering pulp, before pectin extraction	Cloudiness reduced
		ii. The extraction time was reduced to 25 minutes from 45 and 60 minutes	Cloudiness removed and jelly became transparent
Pumello peel	Bitter taste	i. Chopped peel boiled in 1% sodium chloride for 30 minutes before pectin extraction.	Bitterness persisted.
		ii. Chopped peel boiled in 2% sodium chloride for 30 minutes before pectin extraction.	Bitterness reduced to some extent.
		iii. Chopped peel boiled in 3% sodium chloride for 30 minutes before pectin extraction.	Bitterness reduced considerably, still persisting to a limited extent.

Table 8 contd...

		iv. Chopped peel boiled in 4% sodium chloride for 30 minutes before pectin extraction.	Bitterness reduced to a considerable extent, but present as slight after taste
		v. Chopped peel boiled in 6% sodium chloride for 30 min.	De-bittering achieved.
		vi. Chopped peel dipped in 2% lime for 5 hrs. and washed thoroughly before pectin extraction.	Reduction in bitterness was noticed, but not completely absent.
		vii. Chopped peel dipped in 4% lime for 5 hrs. and washed thoroughly before pectin extraction.	Bitterness was reduced, but pectin content was reduced.
		viii. Chopped peel dipped in 6% lime for 5 hrs. and washed thoroughly before extraction.	Loss of pectin and reduction of bitterness evidenced by clot test.
		ix. Chopped peel boiled with sodium hydroxide at 0.175% for 30 minutes and thoroughly washed with water before extracting pectin.	Bitterness removed considerably.
		x. Chopped peel boiled with sodium hydroxide at 0.25, 0.5, 0.75, 1 and 1.5 per cent for 30 minutes and thoroughly washed with water before extracting pectin.	Pectin content along with bitterness was reduced.

Table 8 contd...

		xi. Chopped peel boiled with sodium hydroxide at 1.75 per cent for 30 minutes and thoroughly washed with water before pectin extraction.	Pectin was washed off from the material which was evidenced by clot test.
Pumello peel	Firm consistency	Blended with that of pineapple peel extract at the ratio 1:1.	Firm consistency was removed and gel nature was achieved.
Lime peel	Bitter taste	i. Lime peel boiled with one per cent sodium chloride for 30 minutes and kept overnight. Thorough washing was given before pectin extraction. ii. Lime peel boiled with two per cent sodium chloride for 30 minutes and kept overnight. Before pectin extraction, thorough washing was given. iii. Lime peel was boiled with three per cent sodium chloride for 30 minutes and kept overnight. Washed well before pectin extraction.	No de-bittering Slight de-bittering was observed. Complete de-bittering was observed as evidenced by bitter-less jelly.
Passion fruit rind	Firm consistency	Blended with pineapple peel pectin extract at 1:1 ratio.	Firm consistency of jelly was changed to gel consistency.
Cocoa pod husk	Syrupy consistency and syneresis	Blended with mango peel pectin extract at the ratio of 1:1.	Gel consistency observed.
Mangosteen rind	Syrupy consistency and syneresis	Blended with mango peel extract at the ratio 1:1.	Defects removed and gained gel consistency

Table 9. Effect of storage on quality of jelly (visual observations)

Fruit wastes from which jelly is prepared	Consistency			Syneresis			Colour			Crystallisation			Cloudiness		
	← Months after storage →														
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Mango peel	G	G	G	A	A	A	Golden yellow	Golden yellow	Golden yellow	P	P	P	A	A	A
Jack fruit rind	G	G	G	A	A	A	Pale yellow	Pale yellow	Pale yellow	A	A	A	A	A	A
Pineapple peel	G	G	G	A	A	A	Golden yellow	Golden yellow	Golden yellow	A	A	A	A	A	A
Banana peel	G	G	G	A	A	A	Yellowish brown	Yellowish brown	Yellowish brown	P	P	P	A	A	A
Nutmeg peel	G	G	G	A	A	A	Dark brown	Dark brown	Dark brown	A	A	A	A	A	A
Pumello peel	G	G	G	A	A	A	Pale yellow	Pale yellow	Pale yellow	A	A	A	A	A	A
Passion fruit rind	G	G	G	A	A	A	Pale yellow	Pale yellow	Pale yellow	P	P	P	A	A	A
Cocoa pod husk	G	G	G	A	A	A	Pale yellow	Pale yellow	Pale yellow	A	A	A	A	A	A
Lime peel	G	G	G	A	A	A	Golden yellow	Golden yellow	Golden yellow	A	A	A	A	A	A
Mangosteen rind	G	G	G	A	A	A	Pink	Pink	Pink	A	A	A	A	A	A
Guava jelly (standard)	G	G	G	A	A	A	Brown	Brown	Brown	A	A	A	A	A	A

A: Absent G: Gel P: Present

4.8.1.1 Consistency

Consistency of jelly remained unchanged (gel) throughout the storage period for three months.

4.8.1.2 Syneresis

Syneresis was not observed in any of the jellies during the period of storage.

4.8.1.3 Colour

The colour of all the jellies except that of banana peel, nutmeg rind and mangosteen rind was pale yellow or golden yellow. The colour of banana peel, nutmeg rind and mangosteen rind jelly were yellowish brown, dark brown and pink respectively. No colour change was observed for these jellies during storage under ambient conditions.

4.8.1.4 Crystallisation

Crystallisation (separation of sugar from jelly) was noticed in jelly prepared from pectin extracts of mango peel (Plate 5), banana peel and passion fruit rind, after storage for one month. All other jellies were free from this defect.

4.8.1.5 Cloudiness

None of the jellies became cloudy during the period of storage for three months.

4.8.2 Organoleptic evaluation of jellies under storage

Jellies prepared from different fruit wastes were organoleptically evaluated for criteria viz., appearance, transparency, colour, consistency, taste, aroma, flavour and acceptability as bread-spread, under storage for three months. The results are given in Table 10.

4.8.2.1 Appearance

The appearance of nutmeg rind jelly became less appealing during the course of storage period. The score acquired by it after storing for three months changed from 'very good' to 'good'. Similarly, the appearance of jackfruit rind jelly initially scored as 'good' was scored to a low grade 'fair' as its appearance became less acceptable. Reverse was the case with mango peel, passion fruit rind and pineapple peel jelly, ie. their appearance gained higher values after storage for three months.

4.8.2.2 Transparency

The transparency of jellies of pineapple peel, pumello peel, mango peel and passion fruit rind was improved during storage. All other jellies retained their transparency throughout the period of storage.

4.8.2.3 Colour

On storage, the colour of nutmeg rind, lime peel, pineapple peel, mango peel and passion fruit rind jelly got improved as per the opinion of the evaluators. For all other jellies, the colour remained unchanged throughout the storage period. Some biochemical components responsible for imparting better appealing colour to the product might have developed during the period of storage. Practices of storing the

Table 10. Effect of storage on organoleptic quality of jelly

Criteria	A			B			C			D			E		
	← Months after storage →														
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Appearance	Fair	Fair	Fair	Very good	Very good	Good	Good	Good	Good	Fair	Fair	Good	Good	Good	Fair
Transparency	Fair	Fair	Fair	Good	Good	Good	Good	Good	Good	Fair	Fair	Good	Fair	Fair	Fair
Colour	Good	Good	Good	Good	Very good	Very good	Good	Good	Very good	Fair	Fair	Good	Fair	Fair	Fair
Consistency	Fair	Good	Good	Fair	Fair	Fair	Very good	Very good	Good	Good	Good	Good	Very good	Good	Fair
Taste	Fair	Fair	Good	Good	Good	Good	Satisfactory	Satisfactory	Satisfactory	Good	Good	Very good	Good	Good	Fair
Aroma	Fair	Fair	Good	Good	Good	Good	Good	Fair	Fair	Good	Good	Good	Good	Good	Fair
Fruity flavour	Ab	Ab	P	P	P	Ab	P	P	P	P	P	P	P	P	P
Off-flavour	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Acceptability as bread-spread	Good	Good	Fair	Good	Good	Good	Satisfactory	Satisfactory	Fair	Good	Good	Good	Good	Good	Fair

P: Present
Ab: Absent
1: One months after storage
A: Banana peel jelly
B: Nutmeg rind jelly
2: Two months after storage
C: Lime peel jelly
D: Mango peel jelly
3: Three months after storage
E: Jack fruit rind jelly

Table 10. Contd…

Criteria	A_1			B_1			C_1			D_1			E_1		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Appearance	Fair	Fair	Fair	Satisfa ctory	Satisfa ctory	Satisfa ctory	Fair	Good	Very good	Good	Good	Very good	Good	Good	Good
Transparency	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Good	Good	Good	Very good	Good	Good	Very good
Colour	Good	Good	Good	Fair	Fair	Fair	Fair	Fair	Good	Good	Good	Very good	Good	Good	Good
Consistency	Fair	Satisfa ctory	Satisfa ctory	Satisfa ctory	Fair	Fair	Very good	Very good	Good	Good	Good	Good	Very good	Very good	Good
Taste	Satisf actory	Satisfa ctory	Fair	Satisfa ctory	Satisfa ctory	Satisfa ctory	Good	Good	Good	Good	Good	Good	Fair	Fair	Good
Aroma	Fair	Fair	Fair	Satisfa ctory	Satisfa ctory	Satisfa ctory	Good	Good	Good	Good	Good	Good	Fair	Fair	Fair
Fruity flavour	P	P	P	Ab	Ab	Ab	P	P	Ab	P	P	P	P	P	P
Off-flavour	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Acceptability as bread-spread	Satisf actory	Satisfa ctory	Fair	Satisfa ctory	Satisfa ctory	Satisfa ctory	Good	Good	Good	Good	Good	Good	Fair	Fair	Good

P: Present
Ab: Absent
1: One months after storage
A_1: Mangosteen rind jelly
B_1: Cocoa pod husk jelly
2: Two months after storage
C_1: Passion fruit rind jelly
D_1: Pineapple peel jelly
3: Three months after storage
E_1: Pumello peel jelly

products for development of attractive colour is not uncommon (Girdharilal *et al.*,1998)

4.8.2.4 Consistency

Consistency remained unchanged on storage, with jellies made from mango peel, pineapple peel and nutmeg rind, whereas it got improved in the case of banana peel and cocoa pod husk jelly. The consistency of lime peel, jackfruit rind, mangosteen rind, passion fruit rind and pumello peel jelly was found diminished during storage.

4.8.2.5 Taste

The taste of jellies made from banana peel, mango peel, mangosteen rind and pumello peel jelly was improved on storage. The taste became less acceptable in jackfruit rind jelly. The taste of nutmeg rind, lime peel, cocoa pod husk, passion fruit and pineapple peel jelly remained constant during storage.

4.8.2.6 Aroma

Under storage, good aroma was retained by jelly made from pectin extracts of nutmeg rind, mango peel, passion fruit rind and pineapple peel. The aroma developed for banana peel jelly during storage was more acceptable as per evaluation whereas it became less acceptable with lime peel and jackfruit rind jelly as the score ratings changed from good to fair. Initial aroma was retained by mangosteen rind, cocoa pod husk and pumello peel jelly, during storage period.

4.8.2.7 Fruity flavour

On storage, fruity flavour was retained by jelly of lime peel, mango peel, jackfruit rind, mangosteen rind, pineapple peel and pumello peel. Fruity flavour was absent in cocoa pod husk jelly. With banana peel, fruity flavour was not observed for a storage period of two months, but the jelly gained the flavour during the third month. With nutmeg rind and passion fruit rind jelly, fruity flavour was present for the initial two months, but this disappeared subsequently and found to be completely lost after three months of storage.

4.8.2.8 Off-flavour

None of the jellies were found to have off-flavour initially or during the period of storage for three months.

4.8.2.9 Acceptability as bread-spread

The acceptability of nutmeg rind, mango peel, passion fruit rind and pineapple peel jelly as bread-spread remained constant throughout the period of storage and was scored as 'good' by evaluators. The jelly of banana peel and jackfruit rind were less acceptable as bread-spread. The acceptability of lime peel, mangosteen rind and pumello peel jelly was improved, as bread-spread on storage.

4.9 Rectification of defects noticed in jellies on storage

The defects noticed in jellies during storage, the treatments given for rectification and their effects are presented in Table 11.

Presence of crystals were observed in jelly of mango peel, banana peel and passion fruit rind. Preparation of jelly using pectin extract and sugar at the ratio 1:0.75 was found effective to overcome the tendency of crystallisation of sugar in all the three jellies.

Table 11. Effect of corrective treatments on quality of jellies during storage

Jelly	Defects noticed	Treatments given	Improvement in quality
Mango peel	Crystallisation	i) Jelly was prepared using reduced quantities of sugar, viz., pectin extract and sugar at 1:0.5 ratio	Intensity of crystallisation was reduced
		ii) Prepared the jelly using pectin extract and sugar at 1:0.75 ratio	Crystals were completely absent
		iii) Increased the citric acid content from 0.5 to 0.75 % during pectin extraction	Crystals were completely absent
Banana peel	Crystallisation	Jelly was prepared using pectin extract and sugar at 1:0.75 ratio	Tendency of crystallisation was absent
Passion fruit rind	Crystallisation	Jelly was prepared using pectin extract and sugar at 1:0.75 ratio	Tendency of crystallisation was absent

Discussion

DISCUSSION

The tissues of the edible parts of fruits and vegetables consist of parenchymatic cells, which have a middle lamella consisting mainly of pectins, a primary wall which is a firm gel of pectin, cellulose, hemicellulose and some proteins and sometimes a secondary wall in which cellulose and hemicellulose prevail. Pectic substances account for 0.5 to 4 per cent of the weight of fresh material (BeMiller, 1986)

Pectins are a mixture of polysaccharides, that originate from plants, contain pectinic acid as major components, water soluble and are able to form gels, under suitable conditions. The term pectin will be used in generic sense to designate those water-soluble galacturono -glycans of varying methyl ester content and degree of neutralisation, that are capable of forming gels under suitable conditions. (BeMiller, 1986)

Almost all fruits contain pectin, but the content vary. Same is the case with different fruit wastes. Fruit wastes also contain high as well as low quantity of pectin. It is worth mentioning that majority of pectin produced in the world is extracted from citrus peels. Two citrus processing units in Uttrayan and Kodur are producing major quantity of pectin (Anand and Maini, 1997) produced in India.

The diversified uses of pectin includes its use as a jellying and thickening agent in jams, jellies, ketchups, soups, sauces, as an emulsifier in ice-cream, cod-liver oil, as a foaming enhancer, as a glazing agent in the candied fruits, as a filler in pharmaceutical products, as an agglutator in blood therapy and for sizing in textiles, lacquers and explosive manufacturing.

Though India is one of the largest producer of citrus fruits (pectin is extracted mainly from peels of citrus fruits), about 50 per cent of total requirement of pectin is imported still today. Thus pectin have great commercial potential for utilization in processing industries. So it will be useful, if we could identify fruit wastes containing rich pectin.

Adequate literature are there on extraction of pectin from fruit wastes. Reports on extraction of quality pectin from mango peels (Yu and Delvalle, 1979., Ranganna, 1986; Garg *et al.*, 1994 and Sudhakar and Maini, 1999), nutmeg rind (Pruthi and Krishnankutty, 1985), citrus peel (Anand and Maini, 1997), apple pomace (Anand and Maini, 1997), jackfruit rind (Srivastava and Sanjeevkumar, 1994 and Anand and Maini, 1997) and passion fruit rind (Srivastava and Sanjeevkumar, 1994) are available.

Possibility of extraction of pectin from fruit wastes have added advantages in controlling pollution hazards, increasing the cash flow and thereby increasing the income of the processor. Efficient disposal of wastes also will increase the capacity utilization of processing units (Srivastava and Sanjeevkumar, 1994 and Anand and Maini, 1997).

5.1 Recovery of fruit wastes

The assessment of waste recovery from different fruits done in the present study revealed that minimum 28 per cent of the weight of entire fruit is generated as waste. For nutmeg rind, 82 per cent of waste in the form of rind was obtained. Pruthi and Krishnankutty (1985) and Krishnamoorthy *et al.* (1991) also reported that the outer rind of nutmeg comprises 80 to 85 per cent of the whole nutmeg. As the waste accumulated through nutmeg processing is substantially high, a method for its utilization will be highly appreciated.

Mango fruit generated comparatively low quantity of waste (27.67 %). But mango is highly regarded by the processing industries for product development. Bhalerao *et al.* (1989) and Tandon and Kalra (1991) reported that the processing of mango is increasing with substantial increase in the demand of processed products in domestic as well as in export markets. Since the fruit is being used in huge quantities, waste accumulation will be high.

The possibilities of commercial exploitation of pectin from mango peel had already been reported (Anand and Maini, 1997 and Sudhakar and Maini, 1999). The free and plentiful availability of peels from mango processing industries and the ease in their handling could make it a valuable source of raw material for pectin extraction.

5.2 Evaluation of different methods for pectin extraction

Treatments were tried by varying the quantity of water used for extraction, time of boiling and concentration of different extractants. In total, 17 treatments were tried.

As the recovery and quality of pectin from plant materials depends upon a number of factors like the nature and concentration of acids employed in the extracting media, the ratio of extracting media to plant material under reference and the number of extractions (Pruthi and Krishnankutty, 1985), different treatments were employed for extracting pectin from each waste material. Generally, the extraction of pectin is carried out by boiling the peels in dilute acids (Sudhakar and Maini, 1999).

Employing different treatments for pectin extraction, the superiority of each treatment was evaluated based on nature of clot and dry pectin percentage.

5.2.1 Quantity of pectin extract

As the quantity of water added to the material had an influence on the quantity of pectin extract obtained (Fig.1), the variation in its quantity produced under various treatments cannot be taken as a measure of efficiency of different treatments to extract pectin.

It was found that extending the time of extraction did not influence the quantity of extract (Fig.2).

Since citric acid is the only permitted additive as acid in jelly, the citric acid treatment which gave more quantity of pectin extract was selected out. The quantity of jelly that could be obtained is approximately 1.5 times the quantity of extract (Ranganna, 1986). Thus the quantity of pectin extract is relevant only when pectin extraction is done for preparing jelly. Hence efficiency of different treatments to extract pectin was tested in the present study, based on the nature of clot and dry pectin recovery.

5.2.2 Clot characters and quantity of dry pectin

Lumpsome clot was obtained for those extracts which contained rich pectin whereas the clot appeared as fragmented and granular respectively for those containing medium and poor pectin (Plate 6).

Scoring given to treatments based on clot characters and dry pectin recovery helped to identify effective treatments for extracting pectin from different fruit

Fig.1. Amount of pectin extract obtained when fruit wastes boiled with different quantity of water

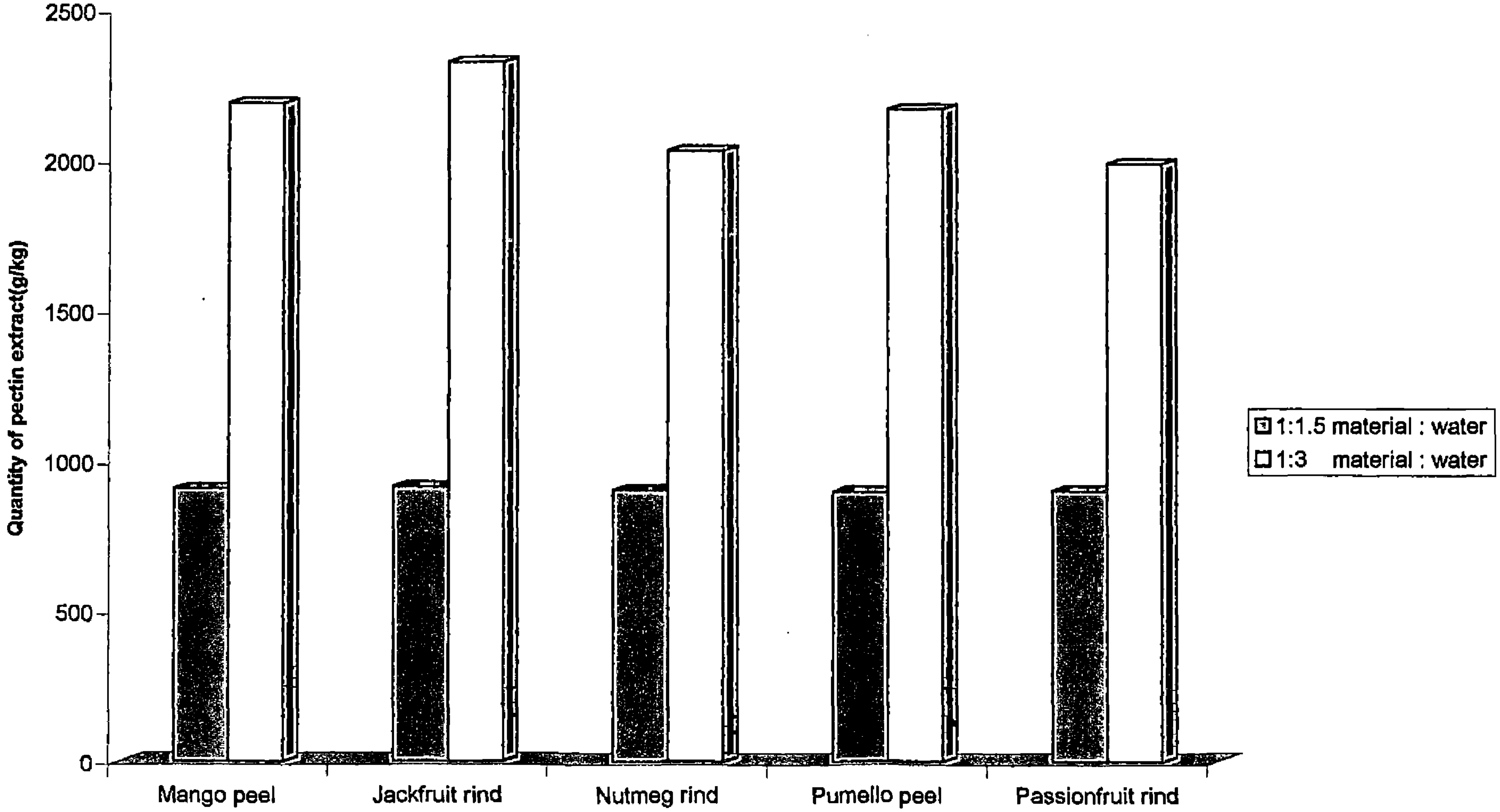


Fig.2. Quantity of pectin extract obtained from fruit wastes when boiled for different time of extraction

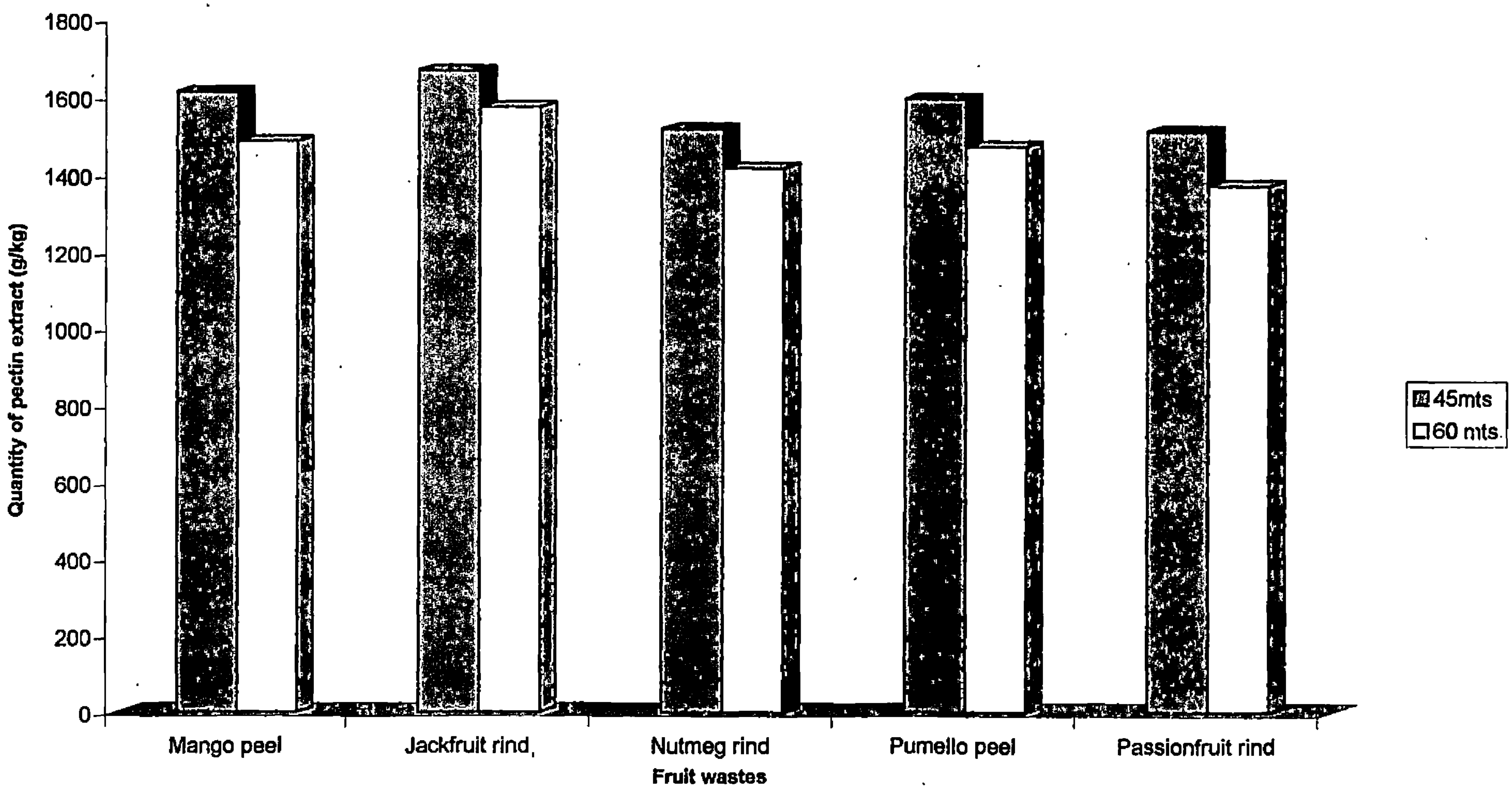
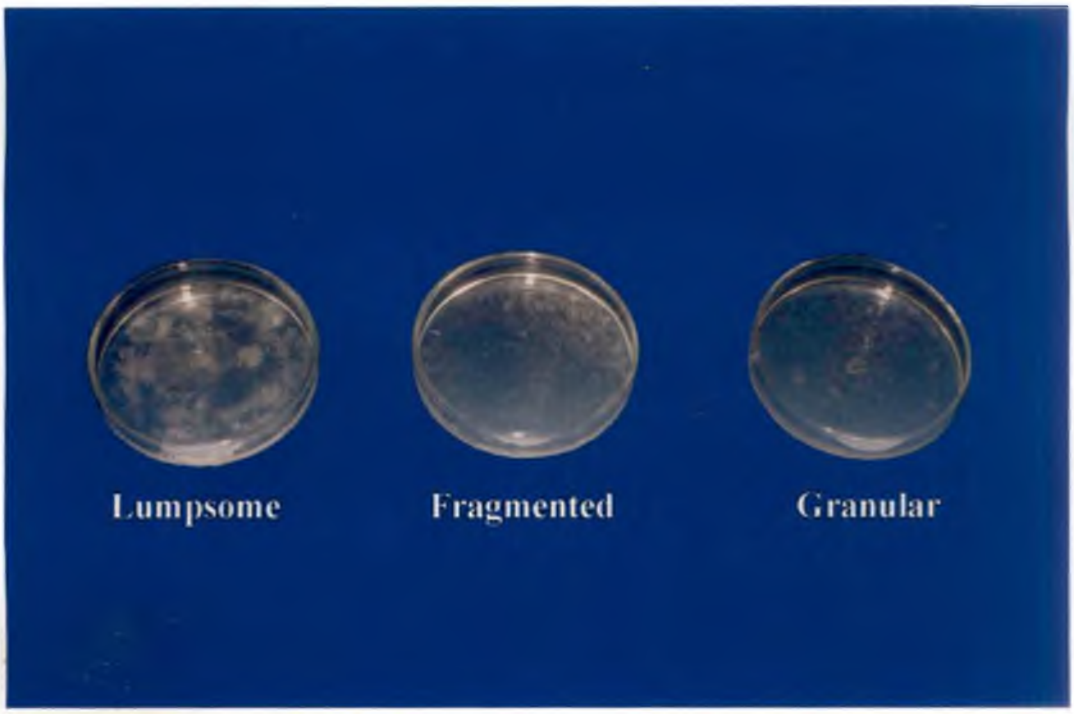


Plate 6. Nature of clot in relation to pectin content in extract



wastes (Table 3).The amount of dry pectin extracted from different fruit wastes under different time of extraction and with different quantity of water are shown in Fig.3 and Fig.4 respectively.

5.3 Selection of efficient method for pectin extraction

The treatments found ideal for extracting maximum pectin from different fruit wastes based on clot characters and dry pectin recovery yielded valuable results.

From mango peel, more amount of pectin could be extracted by adding hydrochloric acid 0.3N at 0.5% and water 1.5 times the quantity of the material and boiling for 60 minutes. The treatments T_8, T_{10}, T_{11} and T_{16} were on par with this treatment. Sudhakar and Maini (1999) standardised the method of extracting pectin from mango peel by adding 0.05 N HCl and water two times the quantity of material and boiling for 60 minutes.

Jackfruit rind responded best for extraction using citric acid 0.75%, by adding 1.5 times water and boiling for 45 minutes as well as boiling with HCl 0.3 N 0.5% for 60 minutes. These methods could recover 8.18% and 7.95% dry pectin respectively. Extraction of pectin from jackfruit rind and preparation of jelly is a common practice (Srivastava and Sanjeevkumar, 1994). As the rind constitute 59% of the fruit, huge quantity will be available for utilisation during the season.

For pineapple peel, none of the methods tried was effective. But there are reports of extracting pectin from pineapple peel using kiesel guhr (Devi and Ingle,1982). This could be attributed to the difference in variety of pineapple used for the purpose. The result also revealed that varietal suitability for pectin extraction is also to be tested as done with different fruits for product development.

Fig. 3. Quantity of dry pectin extracted from fruit wastes under different time of extraction

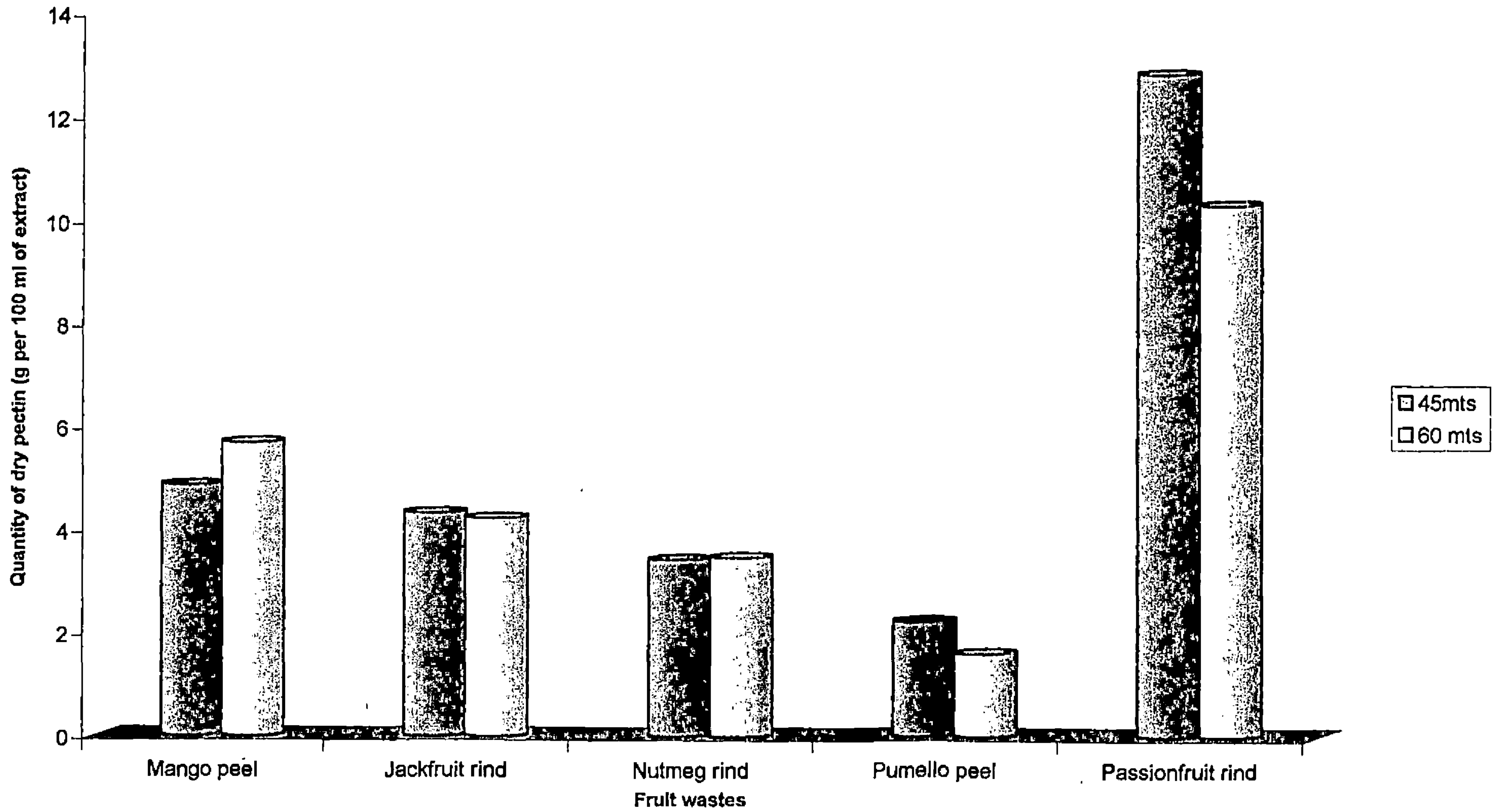
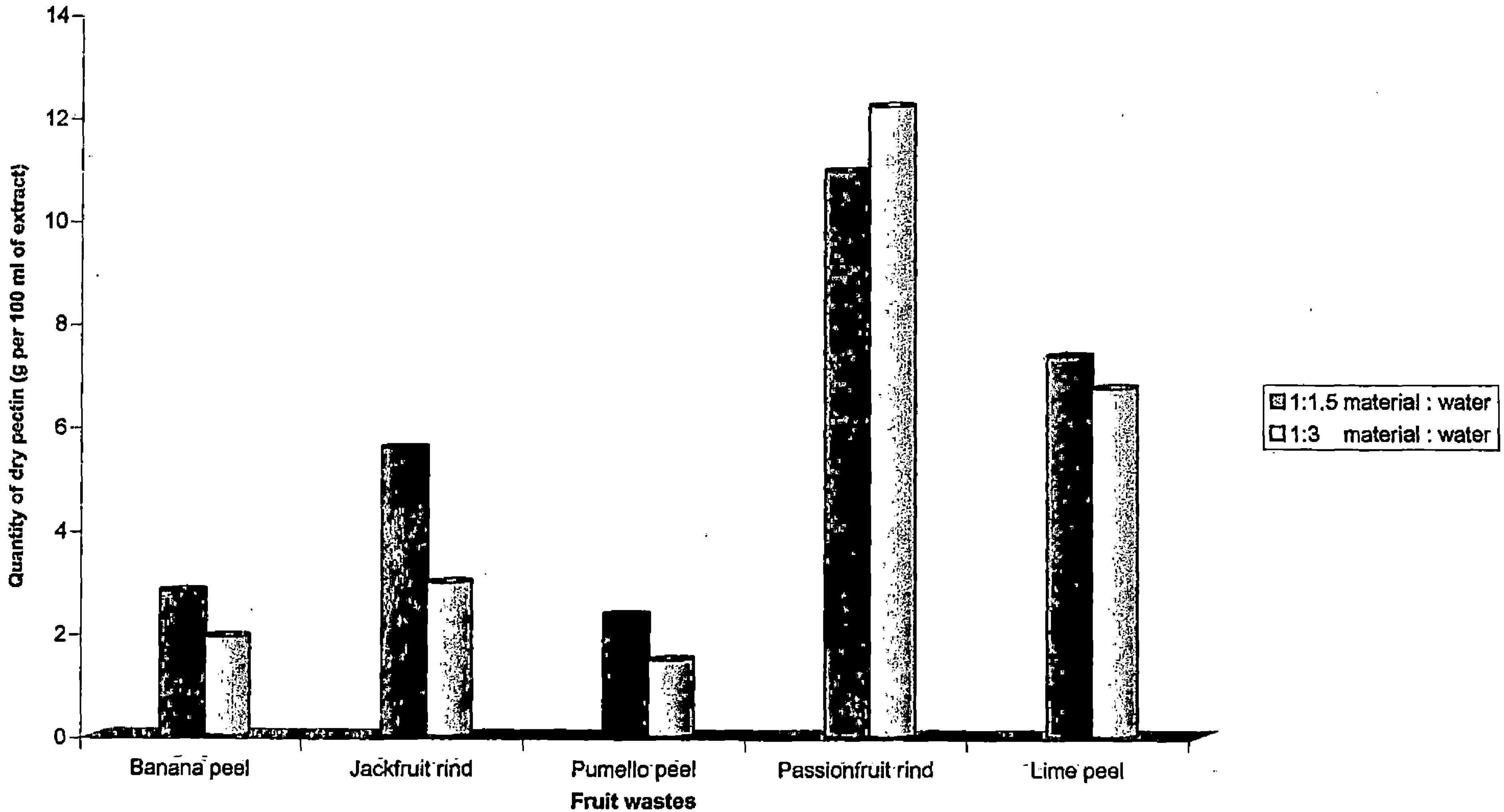


Fig. 4. Quantity of dry pectin obtained from fruit wastes when extracted with different quantity of water



Boiling banana peels with HCl 0.3 N at 0.5% and 1.5 times water to the quantity of material for 60 minutes was found to recover 3.53 per cent dry pectin. The treatments T_6 and T_{13} also gave comparable results.

Banana peel had been identified as a source of pectin by Anand and Maini (1997). As huge quantity of banana are commercially used for product development, identification of suitable methods for extracting pectin from their peels can boost up pectin industries and overcome waste disposal problems.

For nutmeg rind, boiling with HCl 0.1N at 0.5 per cent and water three times the quantity of material for 60 minutes was found to give maximum quantity of dry pectin (4.22%). The treatments T_5, T_{10}, T_{13} and T_{14} were also on par with this. Pruthi and Krishnankutty (1985) got best results when nutmeg rind pectin was extracted with 0.75% hydrochloric acid. Hydrochloric acid may be a better extractant for materials having hard texture. The same was true with mangosteen rind for which the treatments T_9, T_{10} and T_{11} was found best. The firmly adhered cell wall are to be loosened with highly penetrating acid for releasing pectin. Little more hard stature of cocoa pod husk necessitated the use of 0.3 N HCl at 0.5% for extraction. The capacity of hydrochloric acid to extract pectin from peels of different fruits were reported by King (1987) and Turakhozhaev and Khodzhaev (1993).

Only pumello peel responded best for extraction using sodium hexa meta phosphate. Extraction using HCl 0.1 N at 0.5% by boiling with water1.5 times the quantity of material for 45 minutes was also found good . This result is in conformation with that by Atrri and Maini (1996).

An important achievement which remains as a highlight of this study is identifying passion fruit rind as a rich source of pectin. More amount of pectin could be recovered from passion fruit rind by boiling with citric acid 0.75%, by adding water three times the quantity of material for 45 minutes. The treatments T_1, T_2, T_3, T_{13} and T_{16} also could recover a fairly high quantity of pectin.

As citrus peels are reported to be the main source of commercial pectin, adequate literature are available on the content and characters of pectin in them (Anand and Maini, 1997). In the present study, extraction of pectin from lime peel and its characterization was attempted actually to compare the qualities of pectin from other sources with this pectin.

Extraction by adding citric acid 0.75% and water 3 times the quantity of the material and boiling for 60 minutes was found to yield maximum extract enriched with pectin. Commercially citrus peel pectins are extracted using hydrochloric acid and the yield reported is to be 20.2%. As the extraction was attempted prior to the removal of oil from peels in the present study, as against extraction after removing oil in commercial method, the difference in efficiency of extractants might have happened.

Invariably, all the treatments selected as efficient for extracting pectin from different fruit wastes also produced lumpsome clot, revealing presence of rich pectin in the extract.

5.3.1 Efficient citric acid treatment for pectin extraction

As citric acid is the only permitted additive in products, efficient citric acid treatments identified for pectin extraction can be popularised for preparing pectin extracts for jelly preparation.

As sugar is added according to the quantity of pectin extract, the treatments which gave more quantity of extract is also important. In almost all cases, adding water three times to the quantity of material was found to yield more quantity of the extract. When the extracts are enriched with pectin, they are highly suitable for preparing jelly. The present concept of adding water 1.5 times the quantity of material for pectin extraction need re-thinking in this context. For materials which are not rich sources of pectin, adding less quantity of water may be ideal. This may become true in the case of mangosteen rind and cocoa pod husk. Even adding water less than 1.5 times may be better for these materials.

5.4 Quantity of pectin in different fruit wastes

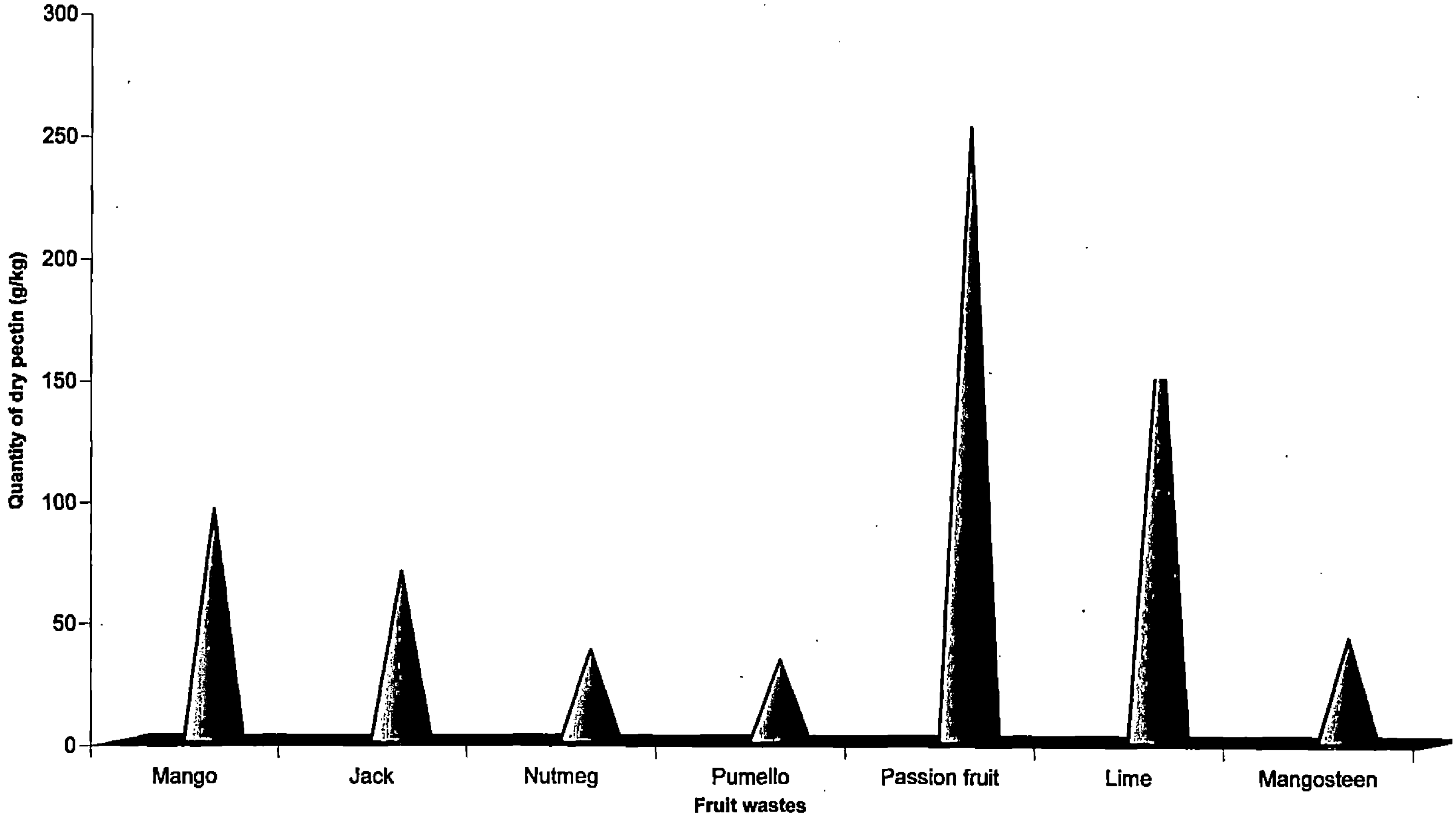
Quantification of dry pectin content in different fruit wastes yielded valuable results. Passion fruit rind was identified as a potential source of pectin, which yielded 252.29g per kg of fruit waste (Fig.5). This quantity is approximately 1.5 times more than that could be obtained from citrus peels.

All other sources tried contain more than 30g of dry pectin per kg of waste. Not only the content, but also the use of different fruits on commercial scale is an important factor governing the waste utilization programme. The wastes, if available in large quantity can be utilized for producing substantial quantities of by-products. Thus considerable quantities of wastes being accumulated through cocoa, banana and nutmeg processing open new avenues for the production of pectin. The fact that about 81% of the weight of a cocoa pod is its husk (Table 1), justify any attempt for utilization of this waste effectively.

Eventhough the use of mangosteen do not come to commercial scale, the waste produced by the use of a single fruit is 71 percentage. So this source can also be used for pectin extraction and product development. Even a few number of jackfruit can generate substantial quantity of waste and the pectin content in them was found 69.64g per kg, thereby functioning as a potential source of pectin as reported by Berry and Kalra (1988) and Srivastava and Sanjeevkumar (1994).

The estimation of pectin content in mango peels revealed that, the huge quantity generated as waste by processing industries (Bhalerao and Mulmuley,

Fig. 5. Quantity of dry pectin in different fruit wastes



1989), could be efficiently utilized for pectin production, as opined by Anand and Maini (1997), Sudhakar and Maini (1999) and Ramteke *et al.* (1999).

Characterisation of pectin was also attempted in the study since scientists working in this field (Ranganna, 1986., Tandon and Kalra,1991 and Sudhakar and Maini, 1999) opines that quality of pectin is an important factor governing its utilization.

Difference in suitability of pectin for use in different products and purposes are due to their variation in character attributes (Ranganna, 1986).

5.5 Characterisation of pectin

Different characters of pectin viz., AUA%, methoxyl content (%), gel grade and acetyl value were determined for pectin extracted from different fruit wastes, as these characters influence the gel forming ability, rate of setting of jelly etc.

5.5.1 Anhydro uronic acid percentage (AUA%)

The dominant and unifying structural feature in pectins is a linear 1-4-alpha linked D-galactopyranosyl-uronic acid chain. Pectin, which is a partly esterified polygalacturonide, contains 10 per cent or more of organic materials, composed of arabinose, galactose or sugars. AUA (%) is essential to determine the purity and degree of esterification and to evaluate physical properties (Ranganna, 1986). The higher galacturonic acid and lower ash content are the two criteria for its purity (Hwang *et al.*, 1992).

The ratio of esterified D-galacturonic acid units to total D-galacturonic acid units is called the degree of esterification (DE) and it strongly influences the solubility, gel forming ability, conditions required for gelation, gelling temperature and gel properties of the preparation (BeMiller, 1986).

It is evident from the data generated on AUA% of pectin from different fruit wastes (Table 5), that purest pectin could be obtained from mangosteen rind and lime peel, compared to other sources. The AUA% for mangosteen rind pectin was 73.16 and for lime peel pectin, it was 72.5%. Among these two, mangosteen is a weaker source of pectin, whereas lime peel is the commercial source. The value of AUA % obtained for lime peel pectin is approximately same as that reported by Sudhakar and Maini (1999), which was 71.2 per cent.

The pectins also have commercial uses as agglutator in blood therapy (GITCO, 1999) and also as thickening agent in medium used for canning of meats. For these purposes, pure pectins are required. Thus the source of pure pectin identified in the present study has relevance in blood therapy as well as in food preservation industries.

The lowest AUA% was for passion fruit rind (46.17%). Passion fruit rind contains high amount of phenolic materials. As the fruits ripen, a part of phenolic materials get converted to sugars. As such, the chance for esterifying pectins with sugar is more. This may be the reason for low AUA% for pectins from passionfruit rind. Cashew apple is another fruit which contain high amount of phenolics. Its AUA% is reported to be 45.1 % (Anand and Maini, 1997).

The AUA of other sources of pectin evaluated in the present study varied from 52.84 to 66.00 per cent.

5.5.2 Methoxyl content and Gel grade

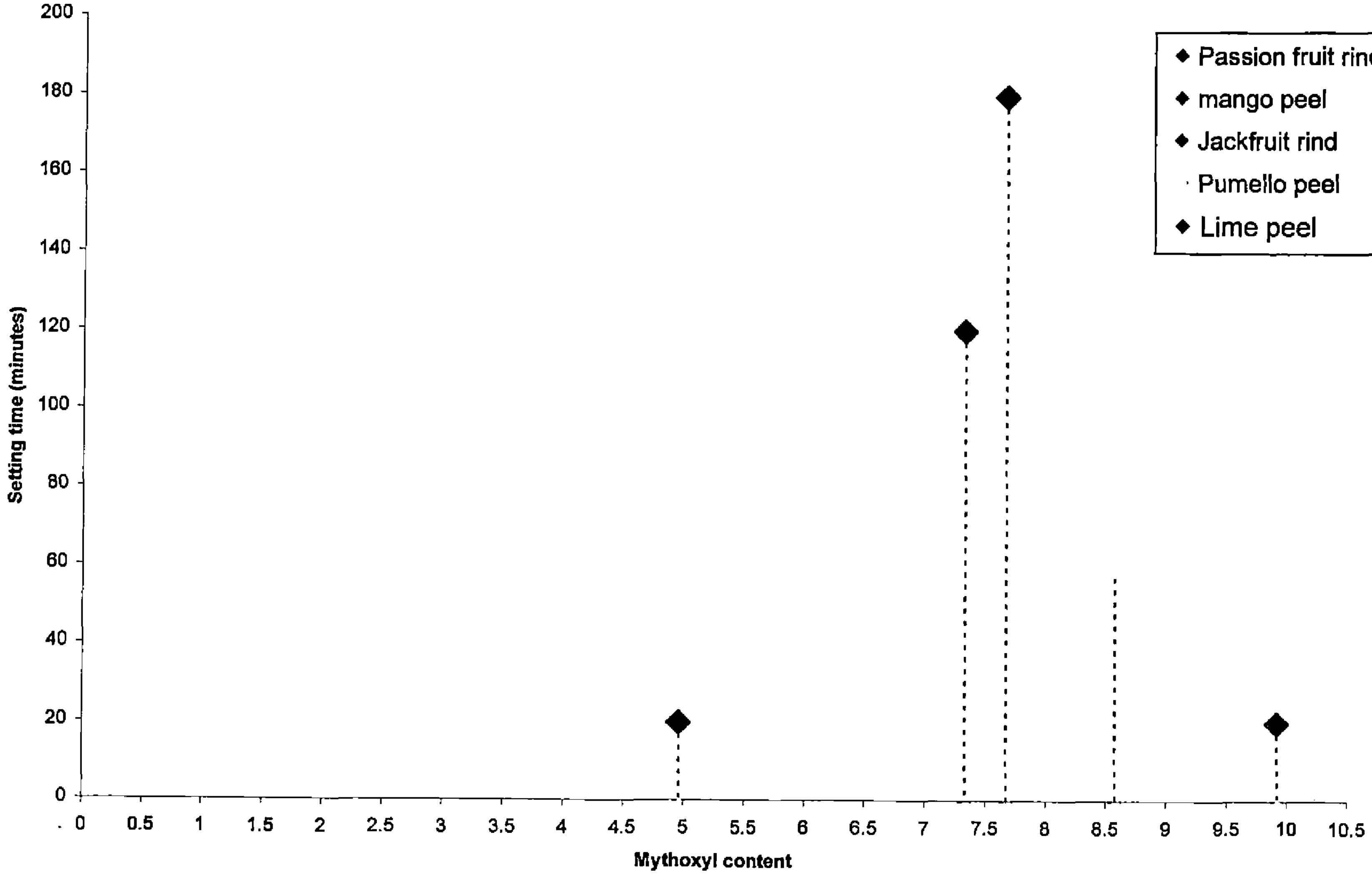
It was described by Ranganna (1986) that pectins from fruits vary in their methoxyl content. Pectins containing 8 to 11 per cent methoxyl content are reported to be good for high sugar gel formations. Low methoxyl pectins viz., less than 7 per cent which cannot form high sugar gels, can form gels with lower concentration of sugar.

In the present study, the gel grade of pectins with methoxyl content in the range of 8 to 11 per cent, was found to vary from 200 to 213. An exception was found with mangosteen rind, whose gel grade was found to be 171, but possessed a very high methoxyl content of 10.54 per cent. Gel grade in the range of 100 to 200 was obtained for those having a methoxyl content in between seven and eight per cent. Passion fruit rind pectin, with methoxyl content less than seven per cent (4.96), recorded a gel grade of 73. Thus the pectin from passion fruit rind can form gels with lower concentration of sugar or they can even form gels without sugar in the presence of polyvalent cat-ions as opined by Ranganna (1986) and Anon (1989). This property of passion fruit rind pectin can be made use of with advantage to prepare low calorie jellies.

The methoxyl content and degree of esterification are two important factors controlling the setting time of pectins, the sensitivity to polyvalent cat-ions and their usefulness in the preparation of low solid gels, films and fibres. It is determined by saponification of pectin and titration of liberated carboxyl group. According to Ranganna (1986), high methoxyl pectins can be converted to low methoxyl pectins by enzymatic breakdown.

Setting time is the interval of time which elapses between the instant at which all constituents of jelly batch are filled into cans or bottles after cooking and the instant at which jellification or gelation of whole into coherent mass occurs (Ranganna, 1986). Pectins with lower degree of esterification exhibit shorter setting time. Usually, pectin with a high methoxyl content of 8 to 11 per cent (DE>70%)

Fig. 6. Relation between methoxyl content of pectins and setting time of jellies



will be a rapid setting one and molecular weight 7 to 10 per cent with degree of esterification 50 to 70 per cent are slow set ones (Ranganna,1986).

The results of the present study is in conformity with the reports that the pectins with methoxyl content in between seven to eight will tend to set slowly (Fig.6). Pectin from mango peel, jackfruit rind, banana peel, nutmeg rind and cocoa pod husk could be included in this category. They set only within two to three hours after preparation. The set of cocoa pod husk jelly was not to that of a standard jelly. This aspect is also discussed elsewhere in this chapter.

Ranganna (1986) also reported that when the methoxyl content lowers below seven per cent, the low methoxyl pectin tends to set rapidly. The same was true with passion fruit rind pectin. It attained a proper set within 20 minutes after preparation. He also reported that if the methoxyl content is high and degree of esterification is more than 70, such pectins are liable to set fast. Lime peel and pumello peel pectins could be included in this category as they exhibited fast setting. Eventhough mangosteen rind pectin had high methoxyl content (10.54%), it did not exhibit a proper set. It was found to be the purest pectin with high AUA% and it can form jelly with low sugar contents. As equal quantity of sugar added to the extract might be more than what is required, the set might have affected. The jelly appeared syrupy. This defect and its rectification done is discussed elsewhere in this chapter.

In the manufacture of jams and marmalade, rapid set pectin is good, while for jelly making, rapid set pectin may cause entrapping of air and hence slow gel pectins are preferred. The rapid set pectin commercially begin to form a jelly at about 88°C, while slow set ones starts jellying at about 54°C. (If it set in 10 to 25 minutes, the pectin is denoted as rapid setting one and when more than 25 minutes, they are denoted as slow setting one (Ranganna, 1986)).

5.5.3 Acetyl value

Pectin consists mainly of polygalacturonate chains and the carboxyl groups are significant determinants of its chemical and biological properties. In plant cell walls, more than 50 per cent of the carboxyl groups are often esterified with methanol. The degree of esterification largely determines the ion-exchange, water-binding, cross linking and hydrogen binding capacities of pectin (BeMiller, 1986). Similarly, properties of pectin in cell walls are sometimes modified by low levels of hydroxyl esterification with acetyl groups. The distribution of acetyl groups in pectin is unknown, but in sugar-beet, pear and apricot pectin, acetyl levels are reported to approach four per cent (Ranganna, 1986).

Sugar-beet pectin contains acetyl group. Perhaps, other pectins may also contain this group. If acetyl group is present in pectin, it inhibits jelly formation (Mc Cready, 1966 and Ranganna, 1986). In the present study, hydroxyl esterification with acetyl group was not obtained for any pectin extract, except that for cocoa pod husk. Eventhough the value was very low, one of the reasons for poor jelly formation noted with cocoa pod husk extract may be due to the presence of this acetyl group.

5.6 Evaluation of jelly quality

5.6.1 Analysis of visual observation

The jelly prepared from different fruit wastes were evaluated for their characters viz., setting time, rate of setting, consistency, syneresis, colour, crystallisation and cloudiness.

5.6.1.1 Rate of setting and setting time

Almost all jellies, except that of passion fruit rind, lime peel and pumello peel exhibited slow setting, whereas passion fruit rind and lime peel jellies exhibited very fast setting nature and achieved proper set within 20 minutes. Pumello peel jelly attained fast setting. Setting property is largely governed by methoxyl content and degree of esterification, which had already been discussed.

Jellies, being the products having sparkling and transparent nature, slow setting pectins are preferred for their preparation. Fast setting ones will have a tendency to entrap air, causing loss of transparent nature. So passion fruit rind pectin can be preferably used for jelly preparation by diluting the extract. It can be also used as good source of commercial dry pectins.

As the pectin content in pineapple peel and cocoa pod husk was very low, proper setting was not achieved for their jellies. Their jelly appeared syrupy due to lack of pectin, as reported by Anon (1989). The pectin extract of mango peel, jackfruit rind, banana peel and nutmeg rind exhibited moderately fast setting (time taken for setting was two to three hours). Their jelly was of desirable (gel) consistency. It is reported that pectins having low degree of esterification or low methoxyl content are slow setting ones (Ranganna, 1986). The result of the present study also agrees with this, as the jellies of mango peel, jack fruit rind, banana peel and nutmeg rind took two to three hours to attain proper set. The pectins which exhibit slow setting nature are reported to be ideal for preparing jellies (Ranganna, 1986). So the pectins having slow setting nature identified in the present study can be utilized best for jelly preparation. Pumello peel jelly was found as a fast setting one, similar to guava jelly.

5.6.1.2 Consistency

The consistency of passion fruit rind and pumello peel jelly appeared firm. As they are rich in pectin, the abundance of pectin in the product in excess to sugar make the product firm.

Pectins are actually cementing materials in the middle lamella of fruit walls. Their presence in excess of what is required will result in a sort of hardness to the product (BeMiller,1986). Alternatively, the pectin content in passion fruit rind extract was made moderate by mixing it with an extract containing low pectin. Here, we used pineapple peel pectin extract. Same was the case with pumello peel extract. Blending its extract with that of pineapple peel at 1:1 ratio removed the hardy consistency of its jelly also.

5.6.1.3 Syneresis

Syneresis is the process of separation of water from the body of the product (Srivastava and Sanjeevkumar, 1994). It was seen with pineapple peel, mangosteen rind and cocoa pod husk jelly. Evidently, these materials contain low pectin, which is not sufficient to bind the sugar added. This may be the reason for separation of water from the product. The excess sugar also gave a syrupy nature to the product.

5.6.1.4 Colour

The colour of jellies (Plate 3) appeared as quite natural, as the colour depend on the components of pigments extracted from the material.

5.6.1.5 Presence of crystals

Initially, crystallisation was absent in all the jellies. Acidity is the crucial factor determining crystallisation (Anon, 1989). The sugar acid blend of all mixtures might be proper to overcome crystallisation. But chances of crystallisation at any time in the storage period of the producf cannot be overruled.

5.6.1.6 Cloudiness

Cloudiness can occur when the pulp material get mixed with the extract (Anon, 1989). This can happen if the fruits are over ripe or heating is done for a long time during extraction. In the present case, the possibility is for the peel pulp to get mixed with the extract.

5.6.2 Organoleptic evaluation

The appearance of all jellies were scored as fair to very good by the evaluators, may be because of acceptability of colour and transparency. Eventhough banana peel jelly was cloudy, the score was fair. The taste score of lime peel jelly and pumello peel jelly required attention as it was satisfactory and poor respectively. Pumello peel jelly was found to have an off-flavour as well.

The major defects noticed in the visual observation as well as organoleptic evaluation were taken care of and improvement was tried further.

5.7 Upgradation of jelly quality

Like other citrus fruits, the single most hindrance in acceptance of lime peel jelly was its bitterness. Probably, this could be due to the presence of limonin and naringin as reported by Premi *et al.* (1995) and Berry (2001) in kinnow orange juice.

In the present study, attempts were made to extract pectin from its peel and prepare jelly. Several methods were seemed to be tried to reduce the bitterness of juice from citrus fruits. These include raising the pH of the juice (Renote and Bains, 1982), suppression of bitterness by addition of sweetening agents (Guadagni *et al.*, 1974), addition of β-cyclodextrin monomer for forming inclusion complexes of limonin (Konno *et al.*, 1981), conversion of bitter principles to non-bitter components in the juice by the action of immobilized bacteria (Hasegawa *et al.*, 1983) and treating the juice with adsorbent XAD-16 (Wilson *et al.*, 1989).

Removing the bitterness of lime peel is a patented process. However, this finding of removal of bitterness from lime peel jelly by boiling the peels in three per cent sodium chloride, prior to pectin extraction appears to be the first of its kind. As the lime peel is not as thick as pumello peel, de-bittering could be achieved in low concentration of salt.

Pumello is a potential under exploited fruit of South India. No much product diversification or preservation methods are seemed to be undertaken in the fruit. However, the attempts for extracting pectin from pumello peel and its subsequent utilization for product preparation is first of its kind in this study. Instead of removing the bitter principles from the extract as done with juice (which appears tedious), treatments were given to the peel to make them get rid of components responsible for bitterness. Peels were treated with sodium chloride, lime and sodium hydroxide at different concentrations with and without boiling for extracting pectin.

Completely de-bittered and highly acceptable jelly was obtained with pectin extracts of peels boiled in six per cent sodium chloride for 30 minutes before pectin extraction. The de-bittering might be due to the inactivation of the enzyme, which is responsible for conversion of laminate-A ring lactone to limonine (Maier *et al.*, 1969) at high temperature combined with high salt concentration. Further increase of salt concentration (6%) resulted in a salty taste to the product.

Attempts were made to overcome the cloudiness of banana peel jelly. Jelly became cloudy when pulp get mixed in the extract (Anon,1995). So extraction was carried out by scrapping off the pulp from peel as well as by reducing the time of extraction from 45 to 60 minutes to 25 minutes. The second treatment was found effective for extraction and the jelly prepared using such extracts was more transparent (Anon, 1989). Banana peel is very soft and it may not require boiling for long time to extract pectin. Such practice might have resulted in mixing of pulp with the extract.

Syrupy nature in jellies from pineapple peel, cocoa pod husk and mangosteen rind was corrected by blending their pectin extracts with that of passion fruit rind and mango peel respectively at 1:1 ratio. According to Ranganna (1986), a jelly will become syrupy if it contain low amount of pectin, which is not sufficient enough to bind the sugar. Pineapple peel and cocoa pod husk contains low pectin, as evidenced through clot test.

Quality of jelly from passion fruit rind was also found improved, due to blending with pineapple peel extract as discussed earlier. Since rich in pectin, passion fruit rind jelly became hard.

5.8 Evaluation of jellies during storage

5.8.1 Analysis of visual and organoleptic evaluation

The organoleptic evaluation of jellies at monthly intervals revealed that the characters like appearance, transparency, colour, consistency, taste, aroma and flavour are modified during storage. However, the modification did not come to the extent of scoring any jelly to an unacceptable one.

5.8.1.1 Transparency

The improvement in transparency of pineapple peel, pumello peel and mango peel jelly can be taken as the beneficial effects of storage.

5.8.1.2 Colour

Similarly, the change of colour of nutmeg rind, lime peel, pineapple peel, mango peel and passion fruit rind jelly towards more acceptable direction is a favourable attribute of storage. Some biochemical components extracted together with pectin may require time to enter in a reaction or conversion for imparting good colour.

5.8.1.3 Consistency

Eventhough the set could be achieved within one to three hours for these jellies, more favourable setting might be occurring when kept for an extended period (Anon., 1989).

5.8.1.4 Crystallisation

Crystallisation (separation of sugar crystals from the jelly) was noticed in jellies prepared using passion fruit rind, banana peel and mango peel, one month after storage. As the gel grade of passion fruit rind was only 73, it can hold only small amount of sugars. As the sugar added might be higher than that is required, excess sugar might have appeared as crystals in the medium. Same might be the reason for crystallisation in jelly of banana peel. Its gel grade was found to be 100. Since mango peel pectin was found to have good gel grade of 200 (same as that reported by Anand and Maini (1997) and Sudhakar and Maini (1999)), the crystallisat ing the defect by increasing the acidity of the medium by adding 0.25% more citric acid, initially for pectin extraction.

5.8.1.5 Taste

The improvement in taste observed with some jellies during storage might be due to some favourable biochemical changes happening in the medium. For jackfruit rind jelly, the biochemical reaction may be reducing its taste. So it is better to use jackfruit rind jelly within two months after preparation.

5.8.1.6 Flavour

None of the jellies were found to develop off-flavour during storage. It can very well presume that there is no deterioration due to fermentation or such process during storage.

The organoleptic characters are highly variable depending upon the taste of evaluators. However, average of scoring based on like and dislike of evaluators for different characters were taken into account and considered as the reflection of general acceptability.

Summary

SUMMARY

The project entitled "Evaluation of fruit wastes as sources of pectin" was carried oust in the Department of Processing Technology, College of Horticulture, Vellanikkara during 1999-2001. The major objectives were to evaluate the yield and quality of pectin from different fruit waste materials and to assess the quality of jelly prepared using these pectins.

An assessment of the quantity of waste materials of different fruits revealed that a substantial portion of their weight is discarded as waste. The lowest amount of waste was from mango and banana and even that accounts to 28 per cent of their weight.

Efficient methods for extracting pectin from different fruit wastes were standardised describing the condition of extracting medium and duration of heating. Extending the time of extraction beyond 45 minutes was not found advantageous. Adding water three times the weight of material was found beneficial for producing more quantity of extract when suitable extractants were used.

The pectin content (dry weight basis) in different fruit wastes was quantified. Passion fruit rind was identified as a rich source of pectin (252.68 g per kg) followed by lime peel (180.48 g per kg), whereas banana peel and cocoa pod husk were weak sources (32.08 and 32.62 g per kg respectively).

The biochemical characterisation of pectins belonging to different sources were done. Mangosteen rind pectin with AUA 73.16 per cent was identified as the purest among pectins analysed. The highest methoxyl content was recorded for this

pectin (10.54%). Passion fruit rind, eventhough contain high amount of pectin, AUA% and methoxyl content recorded was the lowest.

The sugar binding capacity of pectins expressed as gel grade, was found highest for pectin from lime peel (213) and pumello peel (202). It was very low for pectin from passion fruit rind (73).

Acetyl value level in the pectins was not detectable in any fruit waste, except in cocoa pod husk.

Firm consistency of fast setting pumello peel and passion fruit rind jelly was improved by blending with cocoa pod husk and pineapple peel extract respectively in 1:1ratio.

Syrupy consistency of jellies was rectified by adding passion fruit rind pectin extract in 1:1 ratio.

Mango peel, jackfruit rind, banana peel, nutmeg rind and lime peel jellies exhibited a desirable consistency, however, they were slow setting.

Syneresis observed in jellies made from pineapple peel and cocoa pod husk was removed by blending these pectin extract with that of passion fruit rind in the ratio 1:1.

Cloudiness observed with banana peel jelly was removed by reducing the time of extraction to 25 minutes.

The organoleptic evaluation of different jellies resulted in poor rating of pumello peel and lime peel jellies due to their bitter taste. This problem was reduced by boiling the pumello peels in six per cent sodium chloride for 30 minutes following a thorough washing before pectin extraction. For de-bittering of lime peel, the same treatment at reduced concentration of brine (3%) was found sufficient.

Crystallisation noticed in mango peel, banana peel and passion fruit rind jellies during storage, were overcome by reducing the quantities of added sugar to the extent of 0.25%.

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Appendices

Appendix – I

Proforma given to semi trained panel for organoleptic evaluation

Criteria	Score	A	B	C	D	E
Appearance						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					
Transparency						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					
Colour						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					
Consistency						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					
Taste						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					
Aroma						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					
Is there any fruity flavour?						
Yes	√					
No	×					
Is there any off-flavour?						
Yes	√					
No	×					
Acceptability as bread-spread						
Very good	5					
Good	4					
Fair	3					
Satisfactory	2					
Poor	1					

Appendix – II

Quality evaluation of jellies soon after defect rectification (after proper setting)

i) Visual observations

Fruit wastes from which jelly is prepared	Consis-tency	Syner-esis	Colour	Crystalli-sation	Cloudi ness
Mango peel	G	A	Golden yellow	A	A
Jackfruit rind	G	A	Pale yellow	A	A
Pineapple peel	G	A	Golden yellow	A	A
Banana peel	G	A	Yellowish brown	A	A
Nutmeg rind	G	A	Dark brown	A	A
Pumello peel	G	A	Pale yellow	A	A
Passion fruit rind	G	A	Pale yellow	A	A
Cocoa pod husk	G	A	Pale yellow	A	A
Lime peel	G	A	Golden yellow	A	A
Mangosteen rind	G	A	Pink	A	A
Guava jelly (standard)	G	A	Brown	A	A

G: Gel A: Absent

Appendix – II Contd…

ii) Organoleptic evaluation

Criteria	A	B	C	D	E	A_1	B_1	C_1	D_1	E_1
Appearance	Good	Very good	Good	Good	Good	Fair	Fair	Fair	Good	Good
Transparency	Fair	Good	Good	Good	Fair	Fair	Fair	Fair	Good	Good
Colour	Good	Good	Good	Fair	Fair	Fair	Fair	Fair	Good	Fair
Consistency	Fair	Fair	Good	Good	Fair	Fair	Satisfactory	Very good	Very good	Very good
Taste	Good	Good	Satisfactory	Good	Good	Satisfactory	Satisfactory	Very good	Very good	Fair
Aroma	Fair	Fair	Fair	Good	Good	Fair	Satisfactory	Good	Good	Fair
Fruity flavour	Ab	P	P	P	P	P	Ab	P	P	P
Off-flavour	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Acceptability as bread-spread	Good	Good	Good	Good	Good	Satisfactory	Satisfactory	Good	Good	Fair

A: Banana peel jelly
B: Nutmeg rind jelly
C: Lime peel jelly
D: Mango peel jelly
E: Jackfruit rind jelly

A_1: Mangosteen rind jelly
B_1: Cocoa pod husk jelly
C_1: Passion fruit rind jelly
D_1: Pineapple peel jelly
E_1: Pumello peel jelly

EVALUATION OF FRUIT WASTES AS SOURCES OF PECTIN

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

Substantial quantities of wastes are generated as part of fruit and vegetable processing. These wastes suffer from the problem of disposal on one hand, when there are lots of avenues for their utilization on the other hand. The fact that a major portion of pectin required for processing industries are derived from citrus peels, highlight the need of using certain other fruit wastes also as sources of pectin. In this context, the present investigation, 'Evaluation of fruit wastes as sources of pectin' was taken up.

The study revealed that a large portion of the weight of different fruits are discarded as wastes. The pectin content in fruit wastes was found varying and the passion fruit rind was identified as the richest source of pectin (252.68 g per kg) among the different materials analysed. The ideal method for extracting pectin varied, depending upon the material. However, prolonging the time of extraction (by boiling) beyond 45 minutes was not found beneficial.

Owing to its high AUA percentage, mangosteen rind pectin was identified as the purest among different samples of pectin analysed. Its sugar binding capacity was also high (gel grade 171). Passion fruit rind pectin recorded the lowest (AUA% (46.17) and gel grade (73).

The rapid setting nature of passion fruit rind and lime peel pectin revealed their possibility of utilization as thickening agents. The slow setting pectins ntified could be best utilized for jelly making.

The major defects observed with different jellies viz., firm and syrupy consistency, syneresis, cloudiness and bitterness were removed either by changing the composition of extraction media or by blending with the pectin extracts from other fruit wastes. During the period of storage for three months, different jellies were not undergone major changes apart from crystallisation. It was rectified by reducing the quantity of sugar added.

Extraction of pectin and preparation of jelly was found to be a profitable proposition.