International Journal of Applied Environmental Sciences
ISSN 0973-6077 Volume 12, Number 10 (2017), pp. 1777-1801

http://www.ripublication.com

A Review - Pectin from Agro and Industrial Waste

Antony Allwyn Sundarraj[1] and Thottiam Vasudevan Ranganathan[2*]

[1]Research Scholar, Department of Food Processing and Engineering, Karunya University, Coimbatore – 641 114, TamilNadu, India.

[2]Professor, Department of Food Processing and Engineering, Karunya University, Coimbatore – 641 114, TamilNadu, India.*
Corresponding Author

Abstract

Pectins are natural complex heteropolysaccharide which comprise a functionally significant moiety of the primary cell walls of terrestrial plants. Pectin is a carbohydrate found in all fruits and vegetables and is necessary for plant growth. Industrially, it is extracted from citrus peels or apple pomace, and is used as a thickener, water binder and stabilizer in foods, etc. Considering this review sheds a light on the various extracting conditions, characterization, varying time, temperature, pH, functional properties and applications of pectin based polymer techniques.

Keywords: Pectin, food additives, degree of esterification, methoxyl content, Waste Utilization.

INTRODUCTION

Food waste is considered only for products that are directed to a part of food chains leading to "edible products planning to human consumption", [1]. About 18% of the fruit and vegetables production value Rs. 13,300 crores are expected waste annually in India (2014 data). Fruit and vegetables comprises of carbohydrates like sugars, dietary fibres, vitamins and minerals [2].

FOOD ADDITIVES

Food additives are substances which are added to food which either can improve the flavor, texture, colour, taste, appearance as processing aid. Food additives as non-nutritive substances added purposely to food, normally in small quantities, to get better appearance, flavor and storage properties. Food Additives can be classified as colors, flavors, chelating, thickening agents etc., is shown in fig. 1 [3] and (*source:www.intechopen.com).

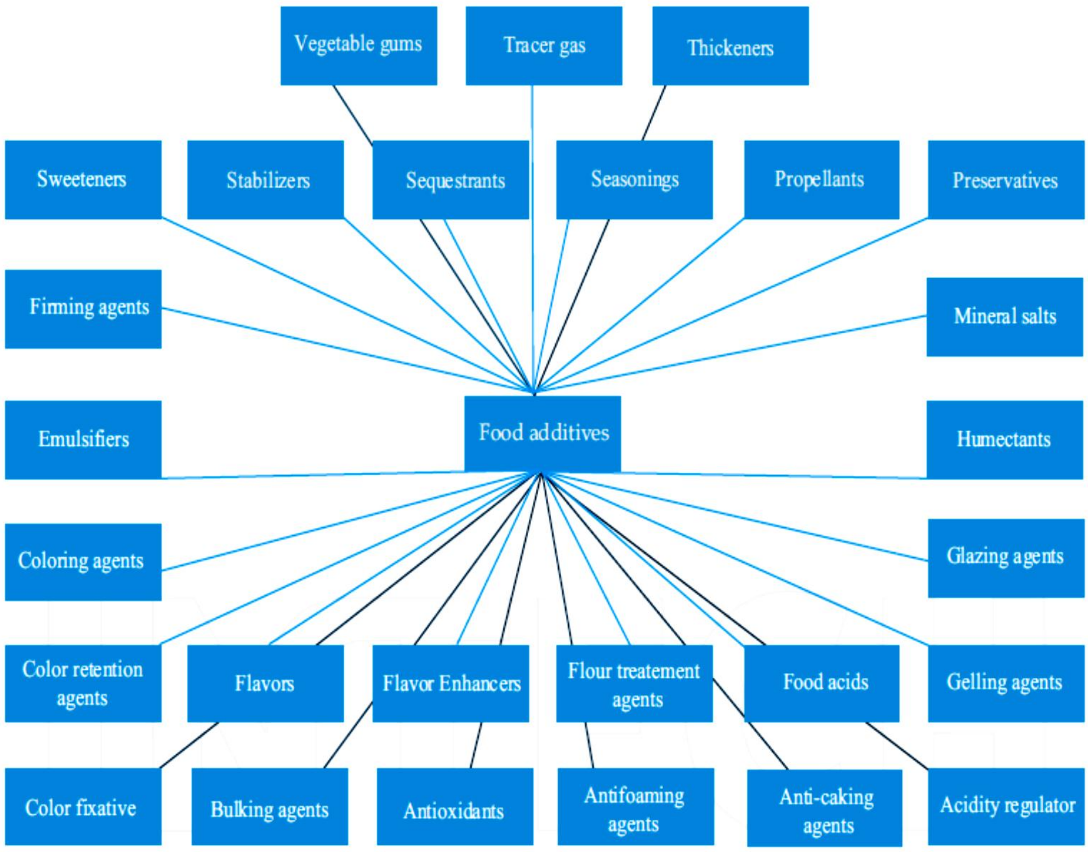

Fig. 1: Classification of Food Additives

PECTIN

Pectin is a structural heteropolysaccharide contained in the primary cell walls of terrestrial plants. It was first isolated and described [4]. Pectin is present not only throughout primary cell walls however in the middle lamella between plant cells [5]. The schematic view of the structural design of the cell wall is shown in (Fig. 2). Pectin is a important by-product that can be obtained from these fruits and vegetable wastes [6].

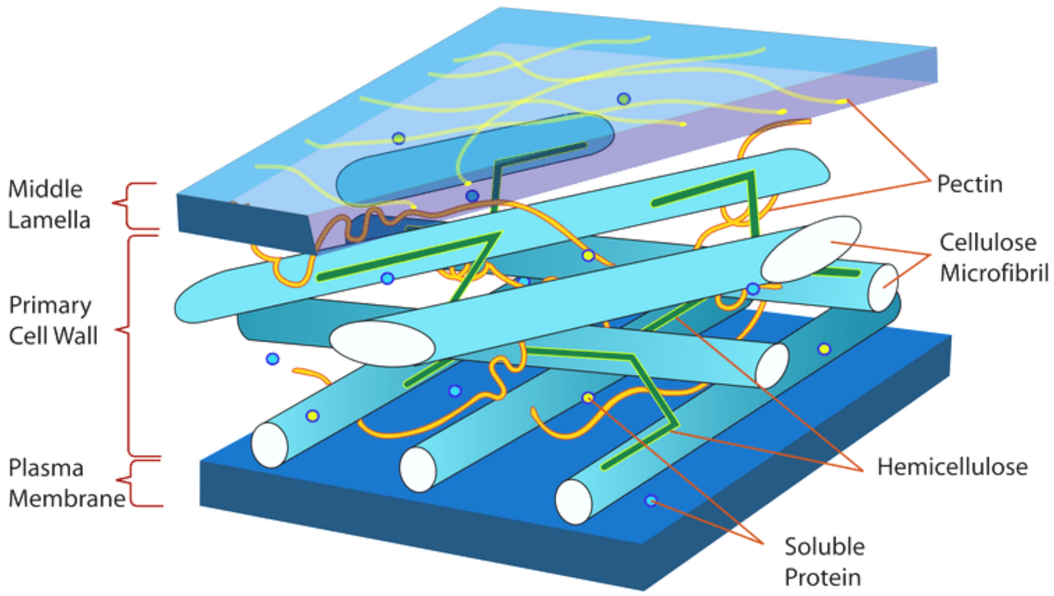

Fig. 2: Schematic demonstration of the structural design of the cell wall

History

The first quotation linking to pectin is found in an English article from 1750 about the preparation of apple jelly [7]. As for commercial production, in the 1930's Hermann Herbsthreith revealed the possible use and purpose of apple pomace, a hitherto discarded by-product of the manufacture of fruit juice [8]. The content of pectic substance vary depending on the botanical source of plant matter. There are four by-products of the agro and food industries that are high in pectic substances such as pomace from apples, sugar beet pulp, citrus fruits and sunflower rinds[9].

Chemistry

Pectin's, also known as pectic polysaccharides, are high in galacturonic acid. Several individual polysaccharides have been recognized and characterized within the pectic group. Homogalacturonans are linear chains of α-(1-4)-linked D-galacturonic acid. [10] studied the substitute galacturonans are characterize by the presence of saccharine residues branching from a backbone of D-galacturonic acid residues.

Functional Groups

Pectins can contain nonsugar substituent's, normally methanol, acetic, phenolic acids and amide groups. Acetyl groups are usually present in the 'hairy' rhamnogalacturonan regions and only present in very low amount in homogalacturonan from apple and citrus fruits [11].

Classification of Pectins

Pectins can be classified according to their degree of esterification (DE). The degree of methylation (DM) is defined as the percentage of carbonyl groups esterified with methanol. If > 50% of the carboxyl groups are methylated the pectins are called high-methoxy pectins (HMP) and < 50% of the carboxyl groups are called low methoxy pectins (LMP). LM pectins can also be further processed to produce amidated (AM) pectins by de-esterification of the LM pectin in an ammonia medium.

a) High Methoxyl pectins (HMP)

HMP need the presence of a high concentration of solids (> 55%) before they can gel, with sucrose used mainly for commercial pectin [12]. This limit the use of HM pectin to sweetened products.

b) Low Methoxyl pectin (LMP)

LMP can gel in the existence of divalent cations, usually calcium. In these systems gelation is due to the arrangement of intermolecular junction zones between homogalacturonic smooth regions of different chains. The arrangement of junction zone is normally attributed to the so called 'egg box' binding process [13]. LMP with a blockwise distribution of free carboxyl groups are very sensitive to low calcium levels. They do not require a low pH, but gel at a pH range of 2-6. Even though high concentrations of solids are not required, the high calcium content results in a bitter after-taste [12].

Sources and Production

The most important source of pectins are citrus peel and apple pomace. They not only have rich pectin content, but are also by-products of the juice manufacturing company [14]. Citrus peel contains high amount of pectin content (25-35% - dry basis), apple pomace (10-15% - dry basis), sugar beet contains (10-20%) and sunflower (15-25% - dry basis) [15].

Worldwide Production of Pectin

Worldwide, roughly 40,000 metric tons of pectin is produced annually and is shown in (Fig. 3). At present the worldwide pectin marketplace expected at 319 million U.S.

dollars. (*source:www.cctt.com.ua).

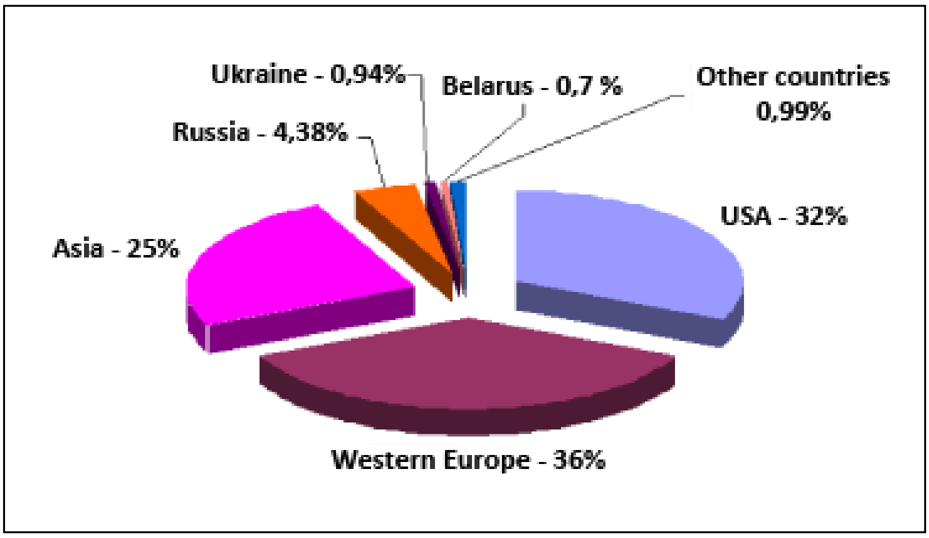

Fig. 3: Worldwide Manufacture of Pectin

"Pectin Market forecast: Worldwide Industry trend, shares, Growth, chance and predict 2017-2022"**,** finds that the worldwide pectin marketplace has grown-up at a Compound Annual Growth Rate of approximately 6% in 2009-2016 and is shown in (Fig. 4 and 5). According to the study, the worldwide pectin requirement is currently being determined by its ability to produce modified textures and its natural association with fruit pulp (*source:www.imarcgroup.com).

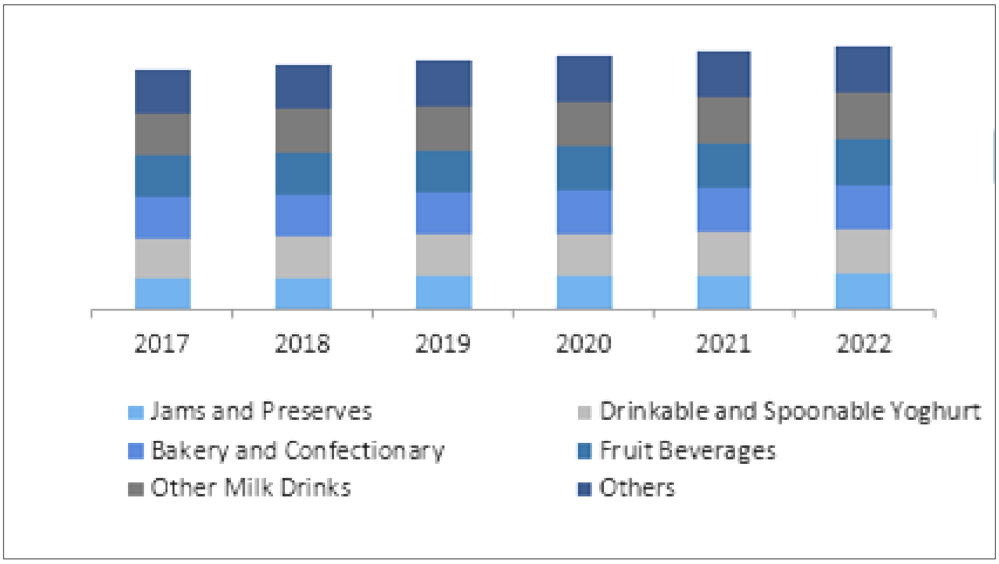

Fig. 4: Worldwide Pectin Applications Market Forecast

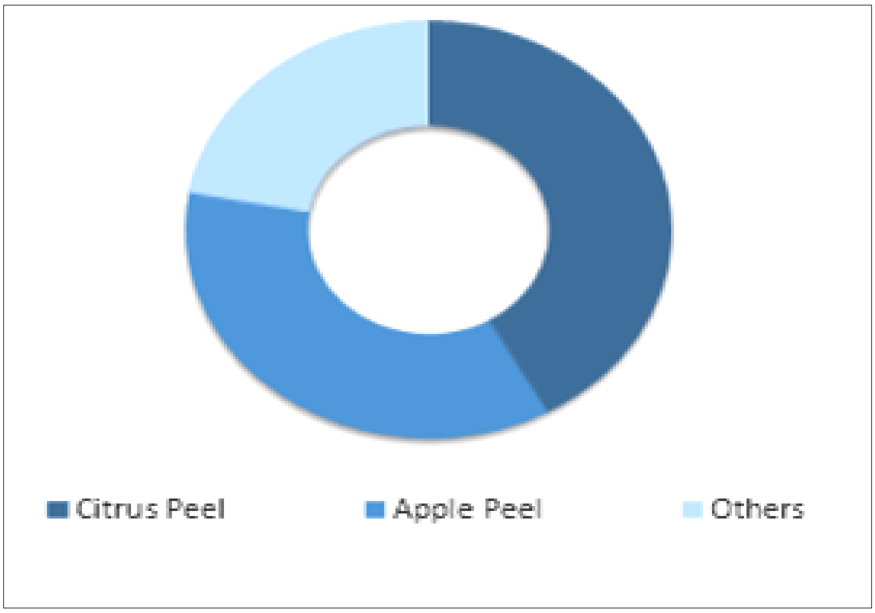

Fig. 5: Global Pectin Market: Breakup by Raw Material (in %), 2016

APPLICATIONS

Pectins are generally used as food additives (E440) with gelling and thickening properties in jams, confectionery products, etc.,[16]. For conventional jams that contains above 60% sugar and soluble fruit solids, high-ester pectin's are used. With low-ester pectin's and amidated pectin's less sugar is needed, so that diet foodstuffs can be made [17].

Extraction of Pectin using Various Acids

Considerable literature pertaining to the extraction of pectin from fruit peels is available.

Isolation of pectin from citrus peels using hydrochloric acid, organic acids, salts and ion exchange resins as extractant [18]. The quality of isolated pectin is reported to be strongly dependent upon the pH of the extracting solution. [19] Pectins were isolated from grapefruit, orange and lemon waste with nitric acid during the 1975-76 Florida citrus season. Temperature and time of isolations were varied while isolating acidity remain constant at pH 1.6 ± 0.05. Parameters for the estimation of isolated pectin from waste were yield, jelly grade and jelly units. Maximum yields of pectin calculated to 150 grade obtained from lemon, orange and grapefruit were 11.0, 8.15 and 6.35%, while highest jelly grades were 254, 225 and 263, respectively. Highest jelly units were found for lemon waste (16.5), followed by orange (12.2) and grapefruit (9.5).

Isolated pectin from firm ripe lawulu fruit using HCL followed by ethanol precipitation yielded 7.3% pectin on wet weight basis and 26.1% on dry weight basis. The isolated pectin contain 0.74% ash, 0.02% acetyl and 7.85% methoxyl content with equivalent weight of 993.5. These values were similar with commercial HMP [20]. [21]pectins from apple pomace with 5% (w/v) aqueous citric acid solutions under different time and temperature according to an experimental design. The DE determined by FT-IR spectroscopy, was linked with increasing temperature and time of extraction.

Extraction of pectin from passion fruit peel using three different acids like citric, hydrochloric or nitric at different temperatures (40 – 90°C), pH (1.2 – 2.6) and extraction times (10 – 90 minutes), with and without skins using a 2^4 factorial design [22]. It was concluded that the optimal conditions for maximization of pectin yield increased from 10% to 70% on the use of citric acid at 80°C and pH 1 with an extraction time of 10 minutes. [23] the isolation of pectin from watermelon rinds and to characterize the best condition for acid extraction. The independent variables were citric acid concentration (0.08 – 5 g/ml) and heating time (20 – 110 minutes). The highest yields were obtain when watermelon rinds was dried and ground to obtain a watermelon flour to be used as raw matter. It was concluded that the data variation and considerably represent the actual relationship between the independent variables and responses, with a correlation coefficient of (0.938) and a (44.9454 %) absolute average percent error. [24] the characterization of apple pectin and its oligogalacturonic fractions resulting from the autochthones apple variety Budimka. After isolation, apple pectin was subjected to controlled enzymatic hydrolysis by polygalacturonase (PG) and pectin lyase (PL) from *Aspergillus niger* and then fractionated by ion-exchange column chromatography. The whole contents of neutral saccharides in the original Budimka apple pectin was detected by HPLC analysis of the 4-nitrobenzoyl derivatives of the sugar and amounted to 5.31 %. [25] the various pre-treatment prior to pectin acid isolation from orange peel. The extraction process involves subjecting the orange peel for a short time to steam pressure varying from 100 to 700 kPa, followed by an instantaneous decompression to vacuum at 5 kPa. The optimal conditions were determined and also the responses surfaces were plotted from the mathematical models using RSM. Moreover, the kinetics of pectin isolation showed that the hydrolysis and the yield of pectins were thoroughly higher than that of control sample of pectin is usually performed in 10-15 minutes.

Acid extraction of novel pectin from chickpea husk (CHP). CHP presented a 67% (w/w) of galacturonic acid, an intrinsic viscosity of 374 mL/g and a viscosimetric molecular weight of 110 kDa [26]. The results attained imply that chickpea husk can be a possible source of a gelling pectin materials. [27] to extract pectin methylesterase (PME) from Valencia orange peels. The pectin methylesterase extracted from orange peels contains almost the same amount of heat stable and labile fraction, and the enzymes cannot be activated by mild heating. The extracts stabilized by Na-benzoate and K-sorbate maintain more than 90% of their pectin methylesterase activity at 4°C for at least 5 months. The pectin methylesterase was successfully used to prepare LMP used in edible film formation in the presence of $CaCl_2$ and to show the potential of using Valencia orange peels as a source of commercial pectin methylesterase.

Pectin extracted from the apple pomace was evaluated for the in vitro inhibition of pancreatic lipase and also pectin was extracted from two different varieties of apples, i.e., *Malus pumila* and *Spondias dulcis* using two different extractants, i.e., hydrochloric and citric acid (CA), separately at pH 2.5. The lipase inhibition was observed to be dependent both source as well as the extractant process used. The maximum lipase inhibition (94.30%) obtained with the pectin extracted from *Malus pumila* by CA process, which is similar to that of the commercial pectin, i.e., 94.15% [28]. The extracted pectin has promising use in the anti-obesity formulations and other applications like personal care products.

Pectin from unshiu orange peels was subjected to chemical alteration by hydroxamic acid. It was found that derivatisation using hydroxamic acid improved the solubility of pectin [29]. [30] evaluate the effect of Celluclast 1.5L concentration on the physicochemical characterization of Gold Kiwifruit pectin. Celluclast 1.5L with medium concentration exhibit the highest viscosity. Varying the different enzyme concentration also influenced the molecular weight distribution. Overall, the study clearly reflects the significance of taking into consideration the amount of cellulytic enzyme added in order to establish the final quality of pectin.

Optimization of nitric acid-mediated and CA extraction of pectin from cacao pod husks (*Theobroma cacao* L.) using RSM [31 & 32]. An initial screening study tested the main parameters influencing yield and uronic acid content by a factorial fractional 3^{3-1} design. Yield was optimized by increasing temperature. From the results obtained experimental value for the pectin yield was 10.1 ± 0.3g/100g dry cacao pod husks using CA extraction as a solvent, with the pectins containing 65.1 ± 0.8g uronic acid, the fraction behaved as a concentrated solution and presented a non-newtonian shear-thinning behavior, well described by Cross Model. [33] the extraction of pectin from different fruits such as orange, apple, guava and grapes using different acids. Hydrochloric, sulphuric and nitric acid were used for extraction of pectin from dried fruit pieces. The resulting pectin content of fruits was compared with different drying methods.

Optimization of pectin extraction from steam distillated orange peels through an experimental factorial design using two different acids; an organic acid (CA) and a mineral one (sulfuric acid) were investigated by RSM [34]. Extraction parameters which are employed in this study are temperature of extraction (X1: 50°C - 80°C), acid concentration (X2: 0.05M - 0.1M) and acid hydrolysis time (X3: 30min -

60min). While results showed, in the case of the sulfuric acid, that all the combinations have a significant effect on pectin yield, however the combined effect of the 3 factor is the most significant followed by the combined effect of time and temperature extraction. Pectin yields varied from 11.32% to 28.23% using CA and from 11.6% to 30.30% using sulfuric acid. [35] chemically modified pectin derivatives by partial esterification of its hydroxyl moieties with various fatty acids (FA: oleic, linoleic and palmitic acid), as well as the initial apple peel pectin were compared and to characterized using diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy. DRIFT spectra determined from pectin to its FA esters are related to the corresponding chemical modifications of a comparable materials measured in KBr / NaCl matrices has revealed noticeable shifts of many polar functional groups. The results secured have implications for careful structural analyses of biopolymers with hydrophilic functional groups by different FTIR spectroscopic methodologies. [36 & 37] extraction and characterization of pomace pectin from gold kiwifruit (A*ctinidia chinensis*) using CA, water and enzyme (Celluclast 1.5L) in terms of physicochemical properties, viscosity and degree of branching. Enzyme extracted pectin showed the highest yield (~ 4.5% w/w) as compared with the acid and water extraction methods (~ 3.6–3.8% w/w). Pectin obtained from several extraction methods showed different degree of branching. Results showed that gold kiwifruit pomace pectin has potential application in various food products. [38] drying operating conditions on the chemical characteristics of the CA extracted pectins from ‘pera’ sweetorange (*Citrus sinensis* L. *Osbeck*) albedo and flavedo using CA. The highest yield value obtained was 38.21%w/w for dried albedo at 70°C and 0.1 ms^{-1} of air velocity. The pectin was assessed for its molecular weight by the method of gel permeation chromatography. [39] extraction and characterization of pectin from red and green grapefruit peels. Grapefruit peels were treated with alcohol and the obtained AIS were subjected to a sequential extraction with hot water and hot 0.5% HCl. Comparative investigation were carried out with purified commercial citrus pectin. The yield of grapefruit peel pectin was 25% (dwb) respectively. [40] evaluated the various functional properties of pectin from dragon fruit (*Hylocereus polyrhizus*) peel from the juice industry and its application in jam processing were investigated. Water holding capacity of the pectin was similar to apple pectin which was 5.50 and 5.45 g/g respectively. For sensory attributes, no significant (p <0.05) differences were observed between the mean scores of the jam produced using dragon fruit peel pectin and apple pectin except for the colour attribute. [41] physicochemical and antimicrobial properties of Cocoa Pod Husk pectin (CPHP) proposed as a flexible pharmaceutical excipient and nutraceutical. Pectin had good microbiological quality and high swelling capacity in aqueous media. CPHP exhibited good physicochemical properties and highly acetylated LMP.

Effect of pH, Temperature and Time for the Extraction of Pectin from Various Fruit Peels

Studies on optimizing the extraction of pectin from grapefruit, orange and lemon peels with time and temperature as variables and using nitric acid [42]. The maximum yield amount of pectin considered to 150 grades and the highest jelly units were found to be 16.5%, 12.2% and 9.5% for lemon, orange and grapefruit respectively. [43] optimum conditions for extraction and precipitation of pectin from mango peels. Due to various changes in pH scale, temperature and time significantly affect the extraction of pectin. Maximum pectin yield was 21.0% was obtained on soaking finely ground and defatted mango peel in H_2SO_4 solution of pH 2.5 at 80^0C for 120 minutes. The chemical characteristic values of mango peel pectin were within the accepted limit of good quality pectin.

Optimization and characterization of pectin through the peel of passion fruit (*Passiflora edulis f. flavicarpa Degener*) and the extracting agents on the pectin of the dry peel of passion fruit. The content of pectin was investigated through the method of acid hydrolysis under the following extracting conditions like pH: 3.0, temperature: 90-95ºC and heating period: 90 minutes. The peel of the passion fruit in the yellow state of ripeness showed the highest content of pectin and the greenish-white state of ripeness showed the best gelling properties [44]. Comparative aspects of pectin extraction from different peels of different variety of citrus fruits like Feutral, Musambi, Malta and Kinnow were optimized according to the standard procedures. pH, temperature and time significantly affected the extraction of pectin [45]. The Feutral yielded maximum pectin followed by Mosambi (18.5%), Malta (15.29%) and Kinnow (14.01%) respectively. In another study pectin was extracted from apple pomace [46], the authors have used a 2^2 factorial design for optimizing the extraction of pectin, time and temperature as variables. Maximum yield of 16.8% pectin was obtained using higher temperature at 100°C for 80 minutes. [47] the effect of different variables including pH (2.5 & 3.5), temperature (80°C & 90°C) and time (60 & 120 minutes) on the yield and quality of pectin from sour orange peels. These parameters affected the extraction significantly and a maximum yield of 16.10% was obtained, at a pH 2.5 temperature of 80°C for 120 minutes. In another study [48], apart from time, pH and solvent as the parameters, the mode of extraction was also used as a variable. Extraction of pectin from orange peels and the effect of different extraction periods, like pH's, types of solvent systems using Microwave and Soxhlet extraction methods. It was concluded that the maximum yield of pectin was found to be 5.27% for 15minutes in a microwave extraction method.

In the case of banana peels, it is reported that the pH of the extraction solution inclined the yield of pectin due to its chemical composition with lower pH values negatively affecting the galacturonic acid content of pectin whereas increasing the yield [49]. In a study conducted on the extraction of pectin from different varieties of apple from Kashmir [50], it was concluded that the yield of pectin content extracted was maximum in the variety of Maharaj – ji at 20.04% followed by Delicious (14.40%) and American apples (11.60%) respectively. [51] pectin extraction from ripened sugar palm meat and young sugar palm meat using different temperature and pH. The ripened sugar palm could give pectin as high as 20% yield at extraction condition of pH 2, 80^{o}C, while the young sugar palm gave only 8.1% yield at pH 3. On the other hand, the extraction of young sugar palm meat at microwave power 800 W at pH 2 with 3 minutes of duration yielded as high as 23.5% of pectin. The results show that sugar palm meat had high potential as a new pectin source. [52] estimate the solutes in orange peel liquid extract used for pectin production based on the optimum extraction conditions. An experimental design was used to examine the influence of the extracting conditions on the yield of the studies. Moreover, the variables were analyzed for significance and optimized, to obtain an optimum solutes yield. [53] optimization of extraction conditions for colchicine from *Gloriosa superba* tubers using RSM. Optimum levels of the significant variables were determined by using Box-Behnken Design (BBD). The most suitable condition for extraction of colchicine was found to be single step isolation at temperature 35°C, pH 7, time 70 minutes, solvent-solid ratio 50:1, mean particle size 0.5 mm and solvent composition 70% ethanol in ethanol-water mixture. At these optimum levels of isolation parameters, the maximum yield of colchicine obtained experimentally was found to be very closed to its predicted value of 0.97% dry weight of tubers.

Extraction and Characterization of gelling and emulsifying pectin fractions from Cacao Pod Husk using different extraction conditions (pH 1.0, 2.0 and 3.0). The results obtained, with respect to yield, chemical, and macromolecular characteristics, showed that 3.7-8.6% cacao pod husk pectin, with 50.9-74.8% galacturonic acid content; 36.7-52.4% methylation degree; 3.2-9.8% acetylation degree, [54]. In another study, [55] various extraction conditions were applied to the effect of temperature, extraction time and substrate – extractant ratio on pectin extraction from cocoa husks. Pectin was extracted from cocoa husks using water, CA at pH 2.5 or 4.0, and hydrochloric acid at pH 2.5 or 4.0. The highest yield of pectin (7.62%) was obtained using citric acid at pH 2.5 at 95^{0}C for 3.0 hours. [56] extraction of pectin from cladode flour of O*puntia ficus indica* was extracted at different ethylenediaminetetraacetate concentrations, temperatures, pH and time. The results of the extracting conditions on the yield, purity and chemical composition of pectin were assessed. The highest pectin yield was observed for pectin obtained under alkaline conditions and 20 % of EDTA. The tested extraction conditions caused only slight changes in the molecular weight of the extracted pectin as a function of time. [57] various effects of extraction parameters and its properties of pectin from pomelo (*Citrus maxima*) affecting pectin yield and its various properties by using single factor and CCD methods. The extraction temperature showed strong influence on the yield and molecular weight, but not on the DE, under the various optimal conditions, then the pectin was measured to be 23.19% and it's DE and MW values were approximately 57.87% and 353kDa. [58] evaluated the various extracting conditions of pectin from lemon pomace under different solvents, temperatures (70, 80, 90 and 100^0C), times (30, 60, 90 and 120 minutes) and maturity stages (premature, mature and over ripen). Preliminary results showed that optimum conditions for the extraction of pectin were found at a temperature of 100^0C by 60 minutes on the basis of pectin yield and equivalent weight extracted with water. Therefore, the premature lemon pomace can be considered as rich source of pectin in terms of yield, methoxyl content, DE and AUA content. [59] various extraction temperature on different properties of the pectin. The maximum yield of citrus peel pectin (CPP) and apple pomace pectin (APP) were 21.95% and 16.68%. Moreover, both CPP and APP scavenged more than 60% DPPH radical and 80% ABTS radical in vitro and the highest proliferation inhibition rates of colon cancer cell HT- 29 by CPP and APP were 76.45% and 45.23% respectively. [60] extraction and characterization of pectin from Saba banana peel wastes. Pectin extraction was carried out by using hydrochloric acid (0.5N, pH 1.5) and (0.5N, pH 1.7). Highest pectin yield was obtained using HCl extracted for pH 4 (17.05% dry basis). The extracted pectin was employed in the process of strawberry jam in order to assess its possible as a gelling agent.

Optimization of fermentation conditions of pectin production from A*spergillus terreus* and its partial characterization [61]. An optimum fermentation condition of pectin production was obtained through a central composite rotatable design in RSM as follows: fermentation time - 30.09 hours, temperature - 25°C and the initial pH in the fermentation medium - 6.9 and the pectin yield reached the maximal value 0.449g/g. The investigation can make it expensive to utilize persimmon peel to produce high methoxyl pectin for food industry, pharmacy and cosmetic manufacture. [62] optimize the aqueous extracting conditions such as solid-liquid ratio (1:5 - 1:15g/ml), pH(2 - 3), extraction time (20 - 60minutes) and extraction temperature (75 - 95°C) on maximum extraction of pectin from durian rinds using 4 factors, 3 levels BBD. The optimum extracting conditions was found to be as follows: SL ratio of 1:10g/ml, pH of 2.8, extraction time (43 minutes) and temperature (86°C). Under the optimal conditions, the experimental pectin yield (9.1%) was well correlated with predicted yield (9.3%) respectively. [63] optimization of processing conditions for the extraction of citrus peel. The dried peel was ground and then subjected to pectin extraction using H2O as solvent. Three treatments with different levels i.e., pH (1, 2, 2.5, 3, 3.5, 4, 4.5 and 5), temperature of solvent (70, 85 and 95°C) and extraction time (0.5, 1, 2, 3, 4 and 5 hours) were evaluated. Development of an cost-effective processing method for pectin extraction from citrus peel, that offer energetic properties nearly identical to those prepared by soxhlet and microwave method using other substrates. Dried citrus peel contains about 30% pectin It has been found that 30 minutes heating at 70°C and pH level 2.5 resulted in 21% pectin extraction followed by 1 hour heating at 85°C at pH level 3.0 and a similar pectin yield. [64] standardization of eco-friendly technique for the extraction of pectin from apple pomace for different time intervals like 15, 30, 45 and 60 minutes at 121°C for 60 minutes followed by precipitation with ethanol was found to be optimum with pectin yield of 13.01% on dry weight basis and AUA content of 43.21%. The standardized method can be used to substitute the chemical extraction procedure for commercial pectin from apple pomace. [65] have investigated the extraction and characterization of pectin from orange peels by using different temperature and time to determine their effects on the % of yield. 10g of orange peels produced 3.5g % yield of pectin at 40˚C in 5 minutes and 4.2g at 80°C in 7 minutes. The results concluded that, the higher extraction time and temperature shows the higher pectin yield. [66] aqueous extraction of pectin from sour orange peel and its preliminary physicochemical properties using various effects of temperature (75-95°C), time (30-90 minutes) and liquid-solid ratio (20-40, v/w) on pectin yield, methoxylation degree and galacturonic acid content using a BBD and RSM. The highest extraction yield (17.95±0.3%) was obtained at temperature of 95°C, time of 90 minutes and liquid-solid ratio of 25 (v/w) respectively.

Passion fruit is one among the popular fruits in Brazil and its annual production represents 70 % of the world production. About 60 % of fruit is mesocarp and epicarp (peel) and contains high levels of pectin that can be extracted using alternative technologies. The aim of the current work was to research the potential of high pressure to extract the pectin from passion fruit peel [67]. The results showed that the extraction yield nearly doubled (from 7.4 to 14.34 %) when at high pressure was used as a pretreatment. High pressure as a pretreatment was found to be an effective and eco-friendly methodology for the extraction of pectin from passion fruit peel. In another study [68] optimization of pectin extraction from banana peels with CA by using RSM. A CCD was used to determine effects of pH (2.0 - 4.5), extraction temperature (70-90°C) and time (120 - 240 minutes) on the yield of pectins extracted from banana peels. The optimized extraction conditions, maximum yield of galacturonic acid while keeping degree of methoxylation at a minimum of 51%, were 87°C , 160 minutes and pH 2.0 respectively. [69] optimization of pectin extraction from pistachio green hull as a new source and the influences of different pH (0.5–2.5), temperature (50–90°C), time (30–150 min) and liquid/solid ratio (10–50 v/w) on the acidic extraction yield and DE of pistachio green hull pectin were studied by using CCD. The optimization of pectin extraction condition showed that the optimal condition was pH of 0.5, temperature (90°C), time (30 min) and liquid/solid ratio (50 v/w). In this condition, the experimental yield (22.1 ± 0.5%) was fine accord among predicted yield (23.42%) respectively. [70] optimization of extraction and physicochemical properties of pectin from carrot pomace and to determine the various effects of pH (0.5 - 2.5), temperature (50 - 90°C), time (30 - 150minutes) and liquid/solid ratio (10 - 50 v/w) on the yield and degree of esterification by CCD for four variables. The results showed that the pectin yield ranged from 5.0 to 15.2% and also, this pectin is classified as LMP. Under the optimal extraction conditions, the galacturonic acid content and emulsifying activity were 75.5 and 60.3% respectively.

Gelling Characteristics and Rheological Properties of Pectin

Estimation of the influence of the degree of esterification on the hydrodynamic properties of citrus pectin's provides an easy demonstration of how chemical difference will influence structural properties of polysaccharides [71]. Five different citrus pectin's with average degree of esterification 77.8, 65.0, 53.9, 37.8 and 27.9%, were studied using capillary viscometry, sedimentation equilibrium and size exclusion chromatography coupled to multi-angle laser light scattering. Hydrodynamic data clearly indicates that increasing chain stiffness with decreasing degree of esterification and electrostatic interactions are important in these conformational changes. [72] isolation and characterization of Pectin from Peel of *Citrus tankan* with a yield of 2.75%. The pectin was composed of D-GalA, D-Gal, L-Ara and L-Rha in the molar ratio of 100:11.3:3.6:2.6. The molecular weight was estimated to be approximately 9:2 - 104. [73] effects of LMP on physiochemical and sensory properties of a reduced-calorie sorrel (*Hibiscus sabdariffa*) jam with sucralose. The puree was processed to jam at 90ºC for 30 minutes, then at 100ºC for two minutes upon the addition of 8% sucralose and three levels (1.5, 2.0, and 2.5%) of calcium added LMP for gelation. This treatment was liked slightly too moderately in texture and overall acceptance.

Comparison of structure and emulsifying activity of pectin extracted from apple pomace and apricot pulp by solubilization at 80˚to 82˚C in acidified medium (HCl 0.5N) at pH 1.5 for 60mins. The emulsifying activity (EA) of the extracted pectin's showed that they were endowed with a surfactant power described by EA varying between 37.03 and 45.87 [74]. Extraction of pectin from Pink Lady apples (*Malus pumila*), which present at physiological maturity an average 50% of red color coverage, to assess whether this variety is characterized by a high (HM) or low methoxyl value (LM). The pectin was extracted with CA, which was tested under three different pH conditions for 60 and 90 minutes and subjected to a constant temperature of 90ºC [75]. The DE of the pectin was measured and then pectin was dehydrated to evaluate its sensory attributes, such as color, flavor, texture and acceptability. [76] extraction of oil, pectin and the physical characteristics of sweet orange. The yield of essential oil obtained from flavedo peel layer is 3.02% and the yield of pectin extracted by acid precipitation method from albedo peel layer was 20.12%. Further, the physicochemical characteristics of pectin were found to be color (brown), moisture content (3.78%), ash (0.62%), degree of methoxylation (9.2%), gel grade (150%) and calcium pectate (7.40%) respectively.

Extraction of pectin from Yuza pomace by using combined physical and enzymatic (CPE) treatment and their characteristics were compared with those of chemically-extracted pectin. The CPE extraction produced pectin with 55% of galacturonic acid and the extraction yield was 7.3%. Also, the pectin obtained by CPE extraction exhibited a higher degree of esterification (46%) than chemically-extracted pectin (41%), which was confirmed by FT-IR [77]. [78] extraction and its characterization of mango peel pectin, as the phytochemical screening was done and micrometric properties like flow behavior, surface tension, viscosity and swelling index. Then, the result shows that the water based extraction method had 25.26% yield of pectin was obtained and it reveals that extracted mango peel pectin exhibited good flow properties.

Extraction of HMP from the fruit peel of *Citrus maxima*. The appropriate condition was the extraction at 80°C without pH adjustment (pH was about 4.5) in 20 times by volume of water. Amberlite XAD-16 polystyrene was used to remove phenolic compounds before concentration and precipitation of pectin [79]. The yield of the obtained pectin was 7.23±0.19%, respectively. In another study, Rheological Characterization of acid pectin samples in absence and presence of monovalent ions due to its use as thickening and gelling agent in the pharmaceutical and food industry [80]. The results obtained are interpreted such that the acid pectin in absence of monovalent ions at pH close to pKa exhibit weak gel or entangled solution properties. [81] have investigated the extraction of Novel Galactoarabinan-Rich Pectin with Gelling Capacity from Soursop Pomace. The effect of the strength of nitric acid-extractant (pH 1.2, 1.6, and 2.0) on the yield, sugar composition, molecular weight and gelling ability of pectin from soursop (*Annona muricata*) and to find out the optimum conditions for manufacturing marketable pectin. The results showed that the yield (3.5-12.9%) of pectin (AMP) extracted from *Annona muricata pomace* was pH-dependent. Partial structural analysis, by enzymatic degradations, suggested that AMP was in the main branched with an unusual galactoarabinan side chain type rather than with arabinogalactan-I. In another study, [82] physicochemical features and gelling capability of cinnamon apple pectin’s were evaluated under different extraction conditions. The results showed that the pectin yield (2.8-10.9%) and sugar compositions. Cinnamon apple pomace appears to be a potentially viable source of marketable pectin’s. [83] extraction and characterization of gelling pectin of the “non-comestible” fruit of *Poncirus trifoliata* using a relatively simple experimental design for optimization, in which only the variable was the extraction pH (1.0, 1.5, and 2.0) on the basis of our previous studies on diverse pectin sources. The results showed that the yield of pectin (7.4% - 19.8%) was strongly influenced by the extraction pH, temperature and time respectively. [84] extraction and characterization of low methoxyl pectin from Cashew Apple pomace under different acid-extraction conditions. The degree of methoxylation (DM) was in the range of 28%–46% and was only slightly affected by the extractant strength, thereby indicating isolation of naturally LMP. [85] have studied on the yield of some structural and rheological properties of acid-extracted pectin's from cashew (*Anacardium occidentale* L.) apple pomace showed that about 25% of pectin's could be produced under various optimized acid conditions. The DM of AOP was 41%, indicating extraction of LMP. Cashew apple pomace, is an industrial cell membrane residue from the production of cashew nut, appears to be a potentially viable source of production of marketable LMP without the requirement for enzymatic and/or chemical demethylation. [86] isolation and characterization of pectin from peel of *Citrus tanakan.* A pectin was extracted from the peel of Citrus tankan with a yield of 2.75%. The uronic acid content was 80.0%, and the degree of methoxylation was 63.2%. The molecular weight was estimated to be around $9{:}2X10^4$ respectively.

Rheological behavior of a high methyl-esterified pectic fraction from tamarillo was evaluated at various concentrations in water and with sucrose (50% w/w, pH 3) [87]. The results suggested tamarillo can be a new source of pectin with potential applications as gelling agents depending on solvent processes. [88] rheological and chemical properties of pectin enriched fractions from different sources extracted with CA from six new potential sources from fruit materials like peach, blackcurrant, raspberry, strawberry, strawberry, plum and a vegetable source like carrot. The uronic acid content of polysaccharides extracted in CA depended on pectinolytic enzymes activity in fresh plant tissues and ranged between 16.5 and 37.1%; which are slightly lower values than those of commercial pectins isolated from citrus and apple. Pectin enriched fractions extracted from seasonal fruit and carrot with CA showed considerable possible as thickening and gelling agents.

Applications of Pectin

[89] extraction of pectin from pumpkin pulp, using an enzyme preparation from *Aspergillus awamori.* In contrast to pumpkin pectin obtained by digestion with cell-free culture medium formed gels with 60% sucrose at pH 3 and the yield was < 14% in comparison with 22%. The main action of the enzyme complex from *Aspergillus* used in this investigation of 3 hours reduction in DE at longer times with a higher content of pectin yield is at (53%) of unesterified galacturonate residues and it's capable of binding lead and other heavy metal cations. [90] the extraction of pectin from orange fruit peel powder was subjected to simple water based soxhlet extraction and pectin was isolated using ethyl alcohol as precipitating agent as a binding property of pectin from pre-compression and post compression for every formulation. It can be concluded for all pre-compression and post compression parameters were found within acceptable range of pharmaceutical purposes. [91] the characteristics of three different pectin's and to see which one is more suitable for industrial applications. Pectin was extracted using alcohol precipitation technique from peels of

lemon, grape and sweet orange. It was characterized using both qualitative and quantitative analysis to determine and compare the color, solubility in cold and hot alkali, pH as well as sugar and organic acid. The result showed that the colors of the pectin from these 3 sources were the same i.e., Brown they were all soluble in hot and cold alkali and water, the moisture content, the methoxyl content and the ash were all higher in the pectin extracted from peels of sweet orange with 95.25, 5.79 and 35%, respectively.

[92] extraction of pectin from orange and lemon peels and its utilized in the production of jam. The quantity of pectin content was extracted from orange and lemon peels on fresh basis was 15.25% and 20.75%. The sensory analysis indicated that all types of jams were accepted by panelists. It's recommended to support the production of jam at home level using local raw materials under strict conditions as well as the using of natural pectin from local fruits for the production of jams. [93] evaluated the influence gelling substance on sensory quality for four blueberry jam formulations. For gelling the following were used: synthetic HMP; synthetic high methoxyl pectin obtain from passion fruit skin isolation; synthetic LMP, and synthetic low methoxyl amidated. Results from the sensory analysis showed clearly, the tasters' preference for the jelly elaborated with synthetic HMP and synthetic low methoxyl amidated pectin. Thus, the results revealed good perspectives for the application of this fruit in the food industry. [94] characterization of pectins extracted from pomegranate peel and their gelling properties, pomegranate peels yielded between 6.8% and 10.1% pectins using (86°C for 80 minutes) nitric acid. The extracted pectins were low methylated and characterized by the majority of homogalacturonan regions. The variations in the pectin gel formation between varieties was recognized to difference in pectin characteristics mainly the hydrodynamic volume and the neutral sugar content.

CONCLUSION

Pectins are likely to play a major role in future. Many studies were performed for the identification of promising techniques to extract, modify and to recover pectin from agro-industrial waste with good quantitative characteristics. So further research is needed to expand new innovative method for the recovery of pectin to overcome the boundaries of existing processes. The need for a more sustainable manufacture of various polysaccharides like pectin and its derivatives based on agro-industrial waste for food processing and production could contributes to the concern of waste management.

ACKNOWLEDGEMENT

I would like to thank Karunya University for their guidance and support.

REFERENCE

[1] FAO. 2001. "Global Food Losses and Food Waste Extent, Causes and Prevention" Study conducted for the International Congress SAVE FOOD! at Interpack2011, Dusseldorf, Germany, p: 1 - 38.

[2] Rudra, S.G., Nishad, J., Jakhar, N. and Kaur, C. 2015. "Food Industry Waste: Mine of Nutraceutical". Intern. J. of Sci. and Environ., 4 (1), 205 - 229.

[3] Pandey, R.M. and Upadhyay, S.K. 2016. "Food Additive". Agri. and Biolog. Sci., 1, 1- 31.

[4] Bracconnot, H. 1825. "Investigations into a new acid spread throughout all plants". Anna. de chim. et de physi., 2 (28), 173 - 178.

[5] McCann, M.C. and Roberts, K. 1991. "The Cytoskeleton Basis of Plant Growth and Form" Lloyd, C.W. London, Academic: pp. 109-129.

[6] Begum, R., Aziz, M.G., Uddin, M.B. and Yusof, Y.A. 2014. "Characterization of Jackfruit (A*rtocarpus heterophyllus*) waste pectin influenced by various Extraction conditions". Agri. and Agri. Sci. Procee., 2, 244 - 251.

[7] Kertesz, Z.I. 1951. "The pectic substances". New York: Interscience.

[8] Canteri, M.H.G., Moreno, L.R., Wosiacki, G. and Scheer, A.P. 2012. "Pectin: from raw material to the final product". Polim., 22(2), 1-13.

[9] Thibault, J.F. 1980. Les substances pectiques. In: Les polymeres vegetaux. Monties B. Editor,Paris: Gaulthier-Vilars.

[10] Belitz, H.D.W. G. and Schieberle, P. 2004 "Chemistry of Pectin". Food Chem., 4th Revised extended edition, Springer, Berlin.

[11] Voragen, G.J., Pilnik, W., Thibault, J.F., Axelos, M.A.V. and Renard, C.M.G.C. 1995. “Pectins”, in: Food polysaccharides and their applications, cap. 10, Stephen A. M. (ed.), Marcel Dekker Inc., New York.

[12] Thibault, J.F. and Rinaudo, M. 1986. "Chain association of pectic molecules during calcium-induced gelation". Biopolym., 25, 456-468.

[13] Ridley, B.L., O'Neil, M.A. and Mohnen, D.A. 2001. "Pectins: Structure, biosynthesis, and oligogalacturonide-related signaling". Photochem., 57 (6), 929 - 967.

[14] May, C.D. 2000. "Industrial pectins-sources, production and applications".

Carbohy. Polym., 12 (l), 79.

[15] Williams, P. A., Sayers, C., Viebke, C., Senan, C., Mazoyer, J. and Boulenguer, P. 2005. "Elucidation of the emulsification properties of sugar beet pectin". J. of Agri. and Food Chem., 53, 3592-3597.

[16] Sakai, T., Sakamoto, T., Hallaert, J. and Vandamme, E.J. 1993. "Pectin, pectinase, and protopectinase: production, properties, and applications". Adv. Appl. Microbio., 39, 213-294.

[17] Yablokov. and Alexey, V. 2009. "Chernobyl Consequences of the Catastrophe for People and the Environment*″.* New York Acad. of Sci., 304 - 309.

[18] Joseph, M.G.H. 1973. "Improved Method for the Extraction of Pectin". Flori. State Horti. Socie., 89, 261 – 262.

[19] Rouse, A.H and Crandall, P.G. 1976. "Nitric Acid Extraction of Pectin from Citrus Peel". Florida State Horti. Socie., 89, 166 - 168.

[20] Gamlath, G.G.S. and Malanganie, K.G.P. 2001. "Properties of Pectin Isolated from Lawulu *(Crysophylum roxbergi* G Don) and Development of Jam and Fruit Leather using Lawulu and Pineapple". Tropic. Agri. Res., 13, 51-60.

[21] Marcon, M.V., Carneiro, P.I.B., Wosiacki, G., Beleski-Carneiro, E. and Petkowicz, C.L.O. 2005. "Pectins from Apple Pomace - Characterization by 13C and 1H NMR Spectroscopy". Annu. Magazine Resonan., 4(3), 56 - 63.

[22] Amboni, R.D.M.C., Rovari, P., Iolanda, M.D.A.S., Luciano, V.G., Edna, R., Reinaldo, F.T. and Marcia, M.C.F. 2008. "Optimization of extraction of high-ester pectin from passion fruit peel (*Passiflora edulis flavicarpa*) with citric acid by using response surface methodology". J. of Biores. Tech., 99, 5561 – 5566.

[23] Asseel, M. R. 2008. "Effect of Different Acids, Heating Time and Particle Size on Pectin Extraction from Watermelon Rinds". J. of Kerbala Univ., 6 (4), 234 – 243.

[24] Liljana, M. and Milos, V.N. 2008. "Characterization and degradation of pectin derived from Budimka apple". J. of Serbia. Chem. Socie., *73* (2), 157–167.

[25] Sannier, F., Rezzoug, S.A., Maache-Rezzoug, Z. and Allaf, K. 2008. "A Thermomechanical Preprocessing For Pectin Extraction From Orange Peel. Optimisation by Response Surface Methodology". Intern. J. of Food Engg., 4, 1 – 9.

[26] Chu, A.R., Vania, Urias-Orona., Jaime, Lizardi-Mendoza., Elizabeth, Carvajal-Millan., Alfonso, A.G. and Benjamin. Ramírez-Wong. 2010. "A

Novel Pectin Material: Extraction, Characterization and Gelling Properties". Intern. J. of Molec. Sci., 11, 3686-3695.

[27] Ahmet, S. and Sebnem, Y. 2010. "Commercially suitable pectin methyl esterase from Valencia orange peels". Turkish J. of Agri. Forestry., 34, 109-119.

[28] Chauhan, G.S. and Amit, K. 2010. "Extraction and characterization of pectin from apple pomace and its evaluation as lipase (steapsin) inhibitor". Carbohy. Polym., 82, 454–459.

[29] Lee, S., Bockki, M., Jongbin, L., Sanghoon, Ko., Kwang-Geun, L. and Sung, H.L. 2011 "Environmentally friendly preparation of pectins from agricultural byproducts and their structural/rheological characterization". Biores. Techn., 102, 3855–3860.

[30] Yuliarti, O., Matia-Merino, L., Goh, K.K.T., Mawson, J.A. and Brennan, C.S. 2011. "Effect of Celluclast 1.5L on the Physicochemical Characterization of Gold Kiwifruit Pectin". Intern, J. of Molec. Sci., 12, 6407 - 6417.

[31] Vriesmann, L.C., Teofilo, R.F. and Petkowicz, C.L.de.O. 2011. "Optimization of nitric acid - mediated extraction of pectin from cacao pod husks (*Theobroma cacao* L.) using response surface methodology". Carbohy. Polym., 84, 1230 - 1236.

[32] Vriesmann, L.C., Teofilo, R.F. and Petkowicz, C.L.de.O., 2012. "Extraction and Characterization of pectin from Cacao Pod Husks (*Theobroma cacao L.*) with citric acid". LWT - Food Sci. and Techn., 49, 108 - 116.

[33] Shakila, B.M, Bharathi, K.G., Gayatrri, P., Nadezhda, H. and Nandhini, J. 2012. "Comparative studies of pectin yield from fruits using different acids". Elixir Food Sci., 42, 6349-6351.

[34] Sayah, M.Y., Chabir, R., Kandri, Y.R.E., Chahdi, F.O., Touzani, H. and Errachidi, F. 2014. "Optimization of pectin extraction from steam distilled orange peels through an experimental factorial design". Intern. J. of Innov. and Appl. Studi., 7(04), 1642 -1649.

[35] Kamnev, A.A., Calce, E., Tarantills, P.A., Tugarova, A.V. and Luca, S.De. 2015. "Pectin functionalized by fatty acids: Diffuse reflectance infrared Fourier transform (DRIFT) spectroscopic characterization". J. of Molec. Struc., 1079, 74 -77.

[36] Yuliarti, O., Goh, K.K.T., Martia-Merino, L., Mawson, J. and Brennan, C. 2015a. "Extraction and Characterization of pomace pectin from gold kiwifruit (*Actinidia chinensis*)". Food Chem., 187, 290 - 296.

[37] Yuliarti, O., Martia-Merino, L., Goh, K.K.T., Mawson, J., Williams, M.A.K.

and Brennan, C. 2015b. "Characterization of gold kiwifruit pectin from fruit of different maturities and extraction methods". Food Chem., 166, 479 - 485.

[38] Zanella, K. and Taranto, O.P. 2015. "Influence of the drying operating conditions on the chemical characteristics of the citric acid extracted pectins from 'pera' sweet orange (*Citrus sinensis L. Osbeck*) albedo and flavedo". J. of Food Engg., 166, 111 - 118.

[39] Mohamed, H. 2016. "Extraction and Characterization of Pectin from Grapefruit peels". M.O.J. Food Process. Techn., 2 (1), 00029.

[40] Izalin, M.Z.N., Kharidah, M., Jamilah, B. and Noranizan, M.A. 2016. "Functional Properties of pectin from dragon fruit (*Hylocereus polyrhizus*) peel and its sensory attributes". J. of Tropic. and Food Sci., 44 (1), 95 - 101.

[41] Adi-Dako, O., Ofori-Kwake, K., Manso, S.F., Boakye-Gyasi, M.EL., Sasu, C. and Pobee, M. 2016. "Physiochemical and Antimicrobial Properties of Cocoa Pod Husk Pectin intended as a Versatile Pharmaceutical Excipient and Nutraceutical". J. of Pharmace., 7608693, 1 - 12.

[42] Rouse, A.H. (1977) "Pectin: distribution, significance" Dalam Nagy SP, Shaw E, Veldhuis MK (eds). *Citrus Science and Technology* (1). The AVI Publishing Company Inc.

[43] Rehman, Z. U., Salariya, A.M., Habib, F. and Shah, W.H. 2004. "Utilization of Mango peels as a source of Pectin". J. of Chem. Socie. of Pak., 26 (1), 74 – 76.

[44] Ferrer, J.R.D., Addosio, G., Paez, M., Marín. and Marmol, Z. 2005. "Obtainment and characterization of pectin through the peel of passion fruit (*Passiflora edulis f. flavicarpa Degener*)". Rev. Factor. Agronom., 22, 237-246.

[45] Rehman, Z. and Salariya, A.M. 2005. "Comparative aspects of pectin extraction from peels of different varieties of citrus fruit". Pak. J. of Food Sci., 15 (1-2), 21 - 23.

[46] Marcia, V.M., Vriesmann, L.C., Wosiacki, G. and Carneiro, E.B. 2005. "Pectins from Apple Pomace". Polimeros: Cienciae Tecnologia., 15(2),127 - 129.

[47] Hussain, A, H. Abid, S. Ali and J. Ali. 2009. "Technique for Optimum Extraction of Pectin from Sour Orange Peels and its Chemical Evaluation". J. of Chem. Socie. Pak., 31, 3.

[48] Langrish, T.A.G., Shi, J. and Yeoh, S. 2007. "Comparisons between different techniques for water-based extraction of pectin from orange peels". Desali., 218, 229 – 237.

[49] Emaga, T. H., Ronkart, S.N., Robert, C., Wathelet, B. and Paquot, M. 2008. "Characterization of pectins extracted from banana peels (*Musa AAA*) under different conditions using an experimental design". J. of Food Chem., 108 (2), 463 – 471.

[50] Mathur, A., Vabprita, S., Bhardwaj, A., Yousu, S., Verma, S.K., Singh, S.K. and Dua, V.K. 2011. "Pectin content as an index for screening different varieties of apple (*Pyrus Malus* L.) of Kashmir (J&K) on the basis of antimicrobial activity". J. of Chem. Pharma. Res., 3(2), 886 – 891.

[51] Supitcha, R. 2011. "Novel source of pectin from young sugar palm by microwave assisted extraction". Procee. Food Sci., 1, 1553 – 1559.

[52] Gebre, T.Y. 2012. "Estimation of Solutes in Orange Peel Extract for Pectin Production". Intern. J. of Sci. and Engg. Res., 3 (10), 1 – 7.

[53] Pandey, D.K. and Banik, R.M. 2012. "Optimization of extraction conditions for colchicine from *Gloriosa superba* tubers using response surface methodology". J. of Agri. Techn., 8(04), 1301 - 1315.

[54] Yapo, B.M. and Koffi, K.L. 2013. "Extraction and Characterization of Gelling and Emulsifying Pectin Fractions from Cacao Pod Husk". J. of Food and Nutri. Res., 1 (4). 46-51.

[55] Chan, S. and Choo, W. 2013. "Effect of extraction conditions on the yield and chemical properties of pectin from cocoa husks". Food Chem., 141, 3752 - 3758.

[56] Jaime, David. Perez-Martınez., Mayra, Sanchez-Becerril., Jose, de.J. Ornelas–Paz., Marco, M.G. lez-Cha vez., Vrani, Ibarra - Junquera. and Pilar, Escalante – Minakata. 2013. "The Effect of Extraction Conditions on the Chemical Characteristics of Pectin from *Opuntia ficus* indica Cladode Flour". J. of Polym. Environ., 21, 1040–1051.

[57] Methacanon, P., Jaruwan, K. and Chaiwut, G. 2013. "Pomelo (*Citrus maxima)* pectin: Effects of extraction parameters and its properties". Food Hydrocolloid., 35, 383 – 391.

[58] Ahmed, M., Azad, A.K.M., Ali, M.A., Akter, Mst. S. and Rahman, Md. J. 2014. "Isolation and Characterization of pectin extracted from lemon pomace during ripening". J. of Food and Nutri. Sci., 2(2), 30 - 35.

[59] Wang, X., Chen, Q. and Lu, X. 2014. "Pectin extracted from apple pomace and citrus peel by subcritical water". Food Hydrocolloid., 38, 129 - 137.

[60] Castillo-Israel, K.A.T., Baguio, S.F., Diasanta, M.D.B., Lizardo, R.C.M., Dizon, E.I. and Mejico, M.I.F. 2015. "Extraction and characterization of pectin from Saba banana [*Musa 'saba' (Musa acuminata x Musa balbisiana*)] peel

wastes: A preliminary study". Intern. Food Res. J., 22 (1), 202 - 207.

[61] Liu, Z., Yao, L. and Fan, C. 2015. "Optimization of fermentation conditions for pectin production *of* A*spergillus terreus* and its partial characterization". Carbohy. Polym., 134, 627 - 634.

[62] Maran, J.P. 2015. "Statistical optimization of aqueous extraction of pectin from waste durian rinds". Intern. J. of Biolog. Macromolec., 73, 92 - 98.

[63] Khan, M., Bibi, N. and Zeb, A. 2015. "Optimization of process conditions for pectin extraction from Citrus peel". Sci. Techn. and Develop., 34(1), 9 - 15.

[64] Chandel, V., Vaidya, D., Kaushal, M., Gupta, A. and Verma, A.K. 2016. "Standardization of eco-friendly technique for extraction of pectin from apple pomace". India. J. of Natu. Produc. and Resour., 7(1) 69 - 73.

[65] Adamu, M.S., Bello, U.M., Bilal, S. and Mashi, A.H. 2016. "Extraction and Characterization of pectin from orange peel". J. of Sci. and Engg. Res., 3(3), 215 -217.

[66] Hosseini, S.S., Khodaiyan, F. and Yarmand, M.S. 2016. "Aqueous solution of pectin from sour orange peel and its preliminary physicochemical properties". Intern. J. of Biolog. Macromolec., 82, 920 - 926.

[67] Olivera, C.F.de., Gurak, P.D., Olivera, F.C., Marczak, L.D.F. and Karwe, M. 2016. "Combined effect of High-pressure and Conventional Heating on Pectin Extraction from Passion fruit Peel". Food Bioprocess. Techn., 9, 1021 - 1030.

[68] Oliveira, T.I.S., Rosa, M.F., Cavalcante, F.L., Pereira, P.H.F., Moates, G.K., Wellner, N., Mazzetto, S.E., Waldron, K.W. and Azeredo, H.M.C. 2016 "Optimization of pectin extraction from banana peels with citric acid by using response surface methodology". Food Chem., 198, 113 - 118.

[69] Charharbaghi, E., Khodaiyan, F. and Hosseini, S.S. 2017. "Optimization of pectin extraction from pistachio green hull as a new source". Carbohy. Polym., 173, 107 - 113.

[70] Jafari, F., Khodaiyan, F., Kiani, H. and Hosseini, S.S. 2017. "Pectin from carrot pomace: Optimization of extraction and physicochemical properties". Carbohy. Polym., 157, 1315 - 322.

[71] Morris, G.A., Foster, T.J. and Harding, S.E. 2000. "The effect of the degree of esterification on the hydrodynamic properties of citrus pectin". Food Hydrocolloid., 14, 227–235.

[72] Tako, M., Yukihiro, T. and Teruko, K. 2008. "Isolation and Characterization of Pectin from Peel of Citrus tankan". Biosci. Biotechn. Biochem.72, 1 – 4.

[73] Badrie, N. and Jacklyn, B. 2010. "Effects of Low-Methoxyl Pectin on

Physicochemical and Sensory Properties of Reduced- Calorie Sorrel/ Roselle (*Hibiscus sabdariffa* L.) Jams". The Open Food Sci. J., 4, 48-55.

[74] Salima, B., Hanachi, G., Djamel, F. and Adel, L. 2010. "Comparison of Structure and Emusifying Activity of Pectin Extracted from Apple Pomace and Apricot Pulp". World J. of Dairy and Food Sci., 5 (1), 79 – 84.

[75] Loyola, N., Paula, P. and Sergio, L. 2011. "Pectin extraction from cv. Pink Lady (*Malus pumila*) apples". Cien. Inv. Agri., 38(3), 425-434.

[76] Girish, M.M., Hashmi, S.Y., Ghatge, P. and Pawar, S. 2012. "Studies on extraction of essential oil and pectin from sweet orange". Open Access Sci. Repor., 1, 291.

[77] Lee, S., Jongbin, L., Jiyoung, Y. and Sanghoon, K. 2012. "Extraction and characterization of pectin from Yuza (Citrus junos) pomace: A comparison of conventional-chemical and combined physical enzymatic extractions". Food Hydrocolloid., 29, 160 – 165.

[78] Malviya, R. and Kulkarni, G.T. 2012. "Extraction, characterization and evaluation of Orange peel as Pharmaceutical excipient". Polym. Medic., 42(3 - 4), 185 - 190.

[79] Sotanaphun, U., Amornrut, C., Nudchanart, K., Malai, S., Panida, A. and Pornsak, S. 2012. "Preparation of Pectin from Fruit Peel of *Citrus maxima".* Silpakor. Univer. of Sci. and Techn. J., 6 (1), 42-48.

[80] Anna, S. and Suk, M.G. 2013. "Rheological Characterization of Acid Pectin Samples in Absence and Presence of Monovalent Ions". Annu. Transac. of the Nordi. Rheo. Socie., 21, 223 – 230.

[81] Yapo, B.M., Besson, V. and Kouassi, L.K. 2013a. "Extraction of Novel Galactoarabinan-Rich Pectin with Gelling Capacity from Soursop Pomace". Natur. Produc. Chem. and Res., 1 (4), 1 – 5.

[82] Yapo, B.M., Besson, V. and Kouassi, K. 2013b. "Cinnamon Apple Pomace Pectins: Physicochemical Characteristics and Gel-Forming Properties". J. of Human Nutr. Food Sci., 1(3), 1019.

[83] Yapo, B.M., Kouassi, L.K. and Besson, V. 2013c. "Extraction and characterization of gelling pectin from the peel of *Poncirus trifoliata* fruit". Agri. Sci., 4 (11), 614-619.

[84] Yapo, B.M. and Kouassi, L.K. 2014. "Extraction and Characterization of Highly Gelling Low Methoxy Pectin from Cashew Apple Pomace". Foods 3, 1 – 12.

[85] Yapo, B.M., Besson, V., Grah, A.M.B., Kouassi, K. and Dago, G. 2014.

"Macromolecular and Viscoelastic Properties of Low Methoxy Pectin from Cashew Apple Pomace". Univ. J. of Food and Nutr. Sci., 2 (1), 1-6.

[86] Tamaki, Y., Konishi, T. and Tako, M. 2016. "Isolation and Characterization of Pectin from peel of *Citus tankan".* Biosci. Biotechn. Biochem. 72 (3), 896 - 899.

[87] Nascimento, G.E.do., Simas-tosin, F.F., Iacomini, M., Gorin, P.A.J. and Corderio, L.M.C. 2016. "Rheological behavior of high methoxyl pectin from the pulp of tamarillo fruit (*Solanum betaceum*)". Carbohy. Polym., 139, 125 - 130.

[88] Mierczynska, J., Cybulska, J. and Zdunek, A. 2017. "Rheological and chemical properties of pectin enriched fractions from different sources extracted with citric acid". Carbohy. Polym., 156, 443 - 451.

[89] Ptichkina, N.M.,Markina, O.A. and Rumyantseva .G.N. 2008. "Pectin extraction from pumpkin with the aid of microbial enzymes". J. of Food Hydrocolloids, 22, 192 – 195.

[90] Srivastava, P. and Malviya, R. 2011. "Extraction, Characterization and Evaluation of Orange peel waste derived Pectin as a Pharmaceutical excipient". The Natur. Produc. J., 1, 65 - 70.

[91] Aina, V.O., Mustapha, M. B., Mamman, O.A., Zakari, A., Haruna, H., Hauwa, H.S.U. and Yagana, B. A. 2012. "Extraction and Characterization of Pectin from Peels of Lemon (*Citrus limon*), Grape Fruit (*Citrus paradisi*) and Sweet Orange (*Citrus sinensis*)". British J. of Pharmaco. and Toxic., 3(6), 259 - 262.

[92] Sulieman, A.M.E., Kawther, M.Y.K. and Zakaria, A.S. 2013. "Extraction of Pectin from Lemon and Orange Fruits Peels and Its Utilization in Jam Making". Intern. J. of Food Sci. and Nutri. Engg., 3(5), 81-84.

[93] Guimaraes, D.H.P., Alves, G.L. and Querido, A.F. 2014. "Influence of gelling substance on sensory quality blueberry (climax) jelly". Intern. J. of Biotech. and Food Sci., 2(6), 116 - 120.

[94] Abid, M., Cheikhrouhou, S., Renard, C.M.G.C., Bureau, S., Cuvelier, G., Attia, H. and Ayadi, M.A. 2017. "Characterization of pectins extracted from pomegranate peel and their gelling properties". Food Chem., 215, 318 - 325.

Website Reference:

www.cctt.com.ua

www.imarcgroup.com

www.intechopen.com