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ORIGINAL ARTICLE

Valorization of Agricultural Waste: Extraction and Characterization of Pectin from Various Fruit Peels for Sustainable Resource Utilization

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ABSTRACT
The major source of pectin extraction is readily available fruit peels, which efficiently converts fruit waste into a useful resource and significantly promotes the use of recycled materials. This study primarily concentrated on the valorisation of agricultural waste, including banana fruit peels, watermelon and muskmelon peels. Ethanol precipitation was employed to extract pectin, and a detailed analysis was done on its physicochemical characteristics, including moisture content, ash content, equivalent weight, esterification degree, solvent holding capacity, water holding capacity, solubility, and alkalinity. The average pectin percentage of muskmelon (8%±0.5%) and watermelon (7.5%±0.3%) was obtained through solvent precipitation method was higher than that of banana (6%±1.5%) peels. The methoxy content (24.128%±0.28%) & (25.833%±0.233%), the moisture content (244.4%±0.36%) & (349.83±0.4), the ash content (5.6±0.2%) & (6%±0.05%), solvent holding capacity (422%±2.26%) & (350%±1.89%) and the water holding capacity (0.4g±0.005g) & (0.68g±0.003g) of the muskmelon and watermelon both have a high pectin yeild. Thus, the peel of watermelon and muskmelon contributed a high yield pectin content. Both have favorable physiochemical characteristics, indicating a strong possibility for safe storage as well as efficient gel formation.
Keywords: *pectin extraction, physiochemical properties, valorization, methoxyl content, fruitwastes*

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INTRODUCTION

Every year the fruit processing industry generally emits over half a billion tonnes of waste. Fruit waste generation and disposal lead to substantial financial losses and serious illness arising from waste water release, landfill pollution, and offensive odour [29]. Furthermore, fruit processing waste (FPW) including peels, pomace, and seed fractions presents a viable source of substrate for the extraction of bioactive compounds like pectin, dietary fibers, lipids, and flavonoids. Plenty of valuable products could be made from FPW by employing a novel bio-refinery approach, with a concentrate on resource efficiency and environmental responsibility in the use of these by-product [3].

Pectin has gained popularity as a gelatine substitute, replacing the substance derived from animals. Pectin is increasingly being used as a primary ingredient in vegetarian or non-animal-ingredient soft confections. Surprisingly, during this period, pectin was the primary ingredient in roughly 46% of newly launched products, demonstrating the ingredient's increasing industrial acceptance [6].

Higher plants comprise pectin, a heteropolysaccharide, a complex polymer of carbohydrates, within their middle lamella and cell walls. Galactosaccharide units represent approximately 70% of the content of

pectin. It also contains other monosaccharides, including glucose, xylose, mannose, fucose, galactose, and arabinose. Pectin is primarily composed of D-galacturonic acid units correlated by α-1,4-glycosidic linkages. The moderating units are formed out of the residues of α-1,4-linked d-galacturonic acid and α-1,2-linked l-rhamnose. The various and significant roles that pectin plays in plant cell structures are defined by these structural components [35].

Pectin is typically categorized into three main domains: the linear homogalacturonan (HG) domain, the rhamnogalacturonan I (RG-I) domain, and the rhamnogalacturonan II (RG-III) domain. Considering the possibility to be acetylated at C-2 or C-3 or methoxylated at C-6, α (1-4) linked-D-galacturonic acid is the most prevalent component of the HG domain. Pectin's capacity to function in food products is defined by the degree of polymerization and the pattern and degree of esterification (DE) of the HG domain, which are influenced by the relative amounts of methyl and acetyl groups. Distinct pectin sources and extraction techniques have different proportions of the RG-I domain, a different significant pectin structure. L-rhamnose residues can bind to side chains of neutral sugars like arabinose and galactose. This structure can also be connected to other substances like coumaric acid or ferulic acid [25].

Pectin demonstrates gel-forming properties under specific conditions, with the gelling mechanism closely linked to its degree of methoxylation (DM). Traditionally, pectin is classified into high methoxy (HM) pectin (DM > 50%) and low methoxy (LM) pectin (DM < 50%). HM pectin exhibits gel formation in the presence of elevated sugar concentrations, typically sucrose or fructose, and under low pH conditions. Conversely, LM pectin forms gels in the presence of divalent ions [4].

As per the FAO (1969), pectin is a safe supplement that can be taken without any limitations on a daily basis. It is typically added to food at concentrations between 0.5% and 1.0%. Peels from citrus fruits, apple pomace, sugar beet pulp, cocoa husk, sunflower heads, beet and potato pulp, soy hull, and duckweed are some of the different sources from which commercial pectin has been extracted. Low ash content (less than 10%), high anhydrogalacturonic acid (more than 65%), and specific molecular weight are characteristics of high-quality pectin [1].

Pectin plays a versatile role as a valuable food additive in the food industry. It assists to stabilize acidic protein-based drinks like yogurt, minimize interaction in marmalades, and strengthen the gel strength of low-calorie jams. Furthermore, pectin effectively prevents undesirable pulp separation by functioning as a thickening and stabilizing agent in fruit juices, desserts, and fermented dairy products. Additionally, it improves viscosity in tomato juice and ketchup, prevents heavy curd formation in milk, emulsifies salad dressing, and maintains cheese texture when heated [22,1].

It is employed in pharmaceutical applications, acting as a binder, thickener, and suspending agent. Medicinally, pectin helps lower blood lipoprotein levels, agglutinates blood for therapy, and prevents various conditions like high triglycerides, cholesterol, diabetes, GERD, colon and prostate cancer, and heavy metal poisoning. Its health benefits extend beyond culinary uses like lowering the risk of coronary heart disease, preventing bowel cancer and hyperlipidemia [37].

In order to extract pectin commercially, raw materials are heated and adjusted to pH 2 using diluted mineral acid. The challenge lies in efficiently extracting the heated pectin extract from the soft solid residue; this is complicated by the fact that viscosity increases as pectin concentration and molecular weight rise. In order to balance efficient extraction and solids separation against operating costs, it is necessary to deal with the difference between using a lot of liquid for extraction and producing a more concentrated extract.

In the investigation of Girma, the acid extraction method was used to demonstrate pectin isolation from mango and banana peels [13]. A hot aqueous extraction method, ethanol precipitation, and lyophilisation were employed to extract pectin from kinnow peel [12]. Mota, isolated pectin from Opuntia robusta peel using both conventional heating methods and microwaves [26]. In the study of Khamsucharit, pectin was isolated and extracted by the method of citric acid extraction [19]. In this research solvent precipitation method was used in extraction of pectin from banana peels, watermelon, and muskmelon peels using ethanol as solvent.

Fruit waste such as banana peels, watermelon, and muskmelon is used in this study to extract pectin. The muskmelon, or *Cucumis melo*, is commonly grown in the Americas, Asia, Northern Europe, and the Mediterranean. It is originated from East Africa [34]. Melons are mostly composed of water, with a low fat content and a high content of carbohydrates, dietary fiber, vitamin C, and provitamin A. Certain melon peels are beneficial for cosmetics and dietary supplements as they possess significant quantities of fiber, pectin, phenolics, and flavonoids [23]. Melon peels exhibit a substantial amount of phenolic compounds, namely luteolin (16.51 mg/100g), chlorogenic acid (8.25 mg/100g), and apigenin-7-glycoside (29.34 mg/100g), in addition to potassium (884.68 mg/100g), calcium (1153 mg/100g) [33].

Citrullus lanatus also referred to as watermelon, is an extensively consumed fruit across the globe, known for its abundance of water (more than 90%), which quenches thirst and offers numerous health benefits [20]. It was a big, juicy fruit which composed of three parts: the edible flesh(68%), seeds inside the flesh(2%), and a rind(30%). In terms of weight, watermelon has about 90% water and 6% sugar. The fruit itself is full of nutrients, including minerals like calcium, iron, magnesium, phosphorus, potassium, and zinc, as well as a variety of essential elements like fats, proteins, and carbohydrates. Moreover, watermelon has a high beta-carotene content, which makes it a good source of vitamins B, C, and most importantly, A [31]. The composition of the rind is as follows: approximately 20% cellulose, 23% hemicelluloses, 10% lignin, 13% pectin, 7 mg/g silica, and 12% minerals free of silica. It has potential as a valuable resource, even though it is frequently thrown away as agricultural waste. It has phenolic compounds, dietary fibers, and the antioxidant citrulline [15, 31].

Banana peels contain plenty of organic matter, such as fats, fiber, carbohydrates, and protein, along with a variety of bioactive compounds with various functions [39]. The nutritional profile of banana peels is impressive, containing 10.09% protein, 18.01% crude fiber, and 5.17% fat. 55.59% is made up of dry matter, with phosphorus and calcium making up 0.10% and 0.36%, respectively. Furthermore, 3727 kcal/kg of large energy is present. Vitamin C from the peel, which is high in vitamins E and B6, functions as an antioxidant, and serotonin may reduce stress, which could increase body weight and feed intake when the animal is under heat stress [38].

In this study pectin was extracted from muskmelon, watermelon and banana peel. In these fruit peel waste, there is a high amount of pectin and also it can replace the commercial pectin and gelatin. The pectin is extracted using the double distillation process and solvent precipitation method using ethanol as solvent and pH adjusted to 2.5. The physiochemical properties of pectin were characterized. According to the results obtained from characterization muskmelon and watermelon has high pectin content in their peel and rind. Gummies also referred to as "gummy candies" or "jellies" are a popular and adaptable candy. Sugar, gelatin, flavourings and other ingredients are blended to formulate this flavourful treat, which is chewy and sweet. In the beginning and most significantly, gelatin is the ingredient that gives gummies their unique and pleasant texture. The extracted pectin from fruit waste are cost effective and can be used as an gelatin substitute. Gummies have gained popularity as a substance in plenty of culinary creations and also as an independent snack. Moreover, the gummy has been used as a delivery system for pharmaceuticals, vitamins, and supplements. Due to their twice purpose, gummies present themselves as a fun and easy way to get your daily dose of vitamins or medications. So in the furture work, pectin will be added as an thickening agent in the formulation of gummies.

MATERIAL AND METHODS

Chemicals

Anhydrous citric acid ($C_6H_8O_7$), 99% ethanol, sodium hydroxide (NaOH), sodium chloride (NaCl), phenol red, hydrochloric acid (HCl), distilled H_2O.

Collection of fruit waste

A variety of fruit peel wastes such like watermelon, banana, and muskmelon were gathered from nearby fruit store and treated with tap water to remove contaminants. After that, the peels were chopped into tiny pieces and allowed to dry in the sun until all of the moisture had been removed. The commercial grinder was used to pulverize the dried peels. The peels were finally ground into a coarse powder after drying. The pectin was extracted from various fruit peel powder [27].

Pectin extraction from different fruit waste

Fruit peel powder were taken in a 1:10 (W/V) ratio. Distilled water was used to dissolve the peel powder. Anhydrous citric acid ($C_6H_8O_7$) was used to reduce the pH 2.5. The mixture was brought to a boil at 80°C for one hour on the hot plate. Following the warm condition, the mixture passed through a filter cloth, and the extract was measured using a measuring jar. To an equal volume of extract, add an equal volume of 99% ethanol. Within a few minutes, the white precipitate forms. In addition, an extraction procedure is used to gather the white precipitate. We had used the centrifugation technique. Centrifuge the extract for 10 minutes at 5000 RPM to collect the white precipitate [21].

$$\text{Pectin yield (\%)} = \frac{\text{Amount of pectin extracted}}{\text{Initial weight of peel powder (Amount of peel powder)}} \times 100$$

Determination of equivalent weight:

5 ml of ethanol were used to dissolve 0.5 grams of pectin. 100ml of dis H2O was used to dissolve 1g of NaCl. In the conical flask, the two solutions are combined with a few drops of phenol red which is used as

an indicator. Titration of the solution was done using 0.1N NaOH. Till the color shift to a pink colour. The equivalent weight determination was done using the below formula [19].

$$\text{Equivalent weight(g/mol)} = \frac{\text{Dry Pectin weight (g)}}{\text{Vol of NaOH} \times \text{NaOH Normality}} \times 1000$$

Methoxy content determination

25 ml of 0.25N NaOH were added to 25 ml of neutral solution that was obtained from the equivalent weight determination step. Once the solution was well combined, it was left to stand for half an hour. Phenol red was used as the indicator, and 25 ml of HCL was added prior to titrated against 0.1N NaOH. The formula was used to determine the methoxy content [30].

$$\text{Methoxy content (\%)} = \frac{\text{Vol of NaOH} \times \text{N of NaOH} \times 3.1}{\text{Dry weight pectin (g)}} \times 100$$

Determination of moisture content

10 gm of various fruit peel powder was weighed and extraction process were carried out. After the centrifugation process, the pellet (wet weight of pectin) were weighed. The following formula was used to determine the moisture content [12].

$$\text{Moisture (\%)} = 1 - \frac{\text{Dry weight of pectin}}{\text{Fresh weight of pectin}} \times 100$$

Determination of ash content

1g of the pectin was burned for 4 hours at 600°C in muffle furnace in order to obtain the amount of ash. After that, the ash was allowed to cool in a desiccator filled with blue silica gel [12].

$$\text{Ash (\%)} = \frac{W2 - W1}{W2} \times 100$$

Where, W_1 – Final sample weight,
W_2 – Initial sample weight

Alkalinity test

An alkalinity test was performed on the ash by dissolving it in 25 ml of 0.1 N HCI. After being gradually brought to a boil, the mixture was cooled. Subsequently, 0.1 N NaOH and phenolphthalein were used to titrate it. In addition, 25 ml of the HCI were used for a blank titration. The alkalinity of pectin was determined using the following formula [5].

$$\text{Alkalinity (\%)} = \frac{(\text{Blank} - \text{Titre})\,(\text{Normality of alkali})\,(60)\,(100)}{(\text{Weight of ash})\,(1000)}$$

Degree of esterification

Ethanol was used to disperse the dried pectin (0.2g) and after it was dissolved in 20ml of distilled H_2O. In order to guarantee total dissolution, the sample solution has been placed in a water bath shaker setting at 45°C. The solution mixture was cooled before three drops of phenolphthalein indicator were added, and it was titrated against 0.1N NaOH until the pink color appeared. It is recognized as the titration's starting volume. In addition, 10 ml of 0.1N NaOH were combined and shaken hard to neutralize the polygalacturonic acid. It was kept aside for 2 hours at 37°. After adding 10 ml of 0.1N HCl to the sample mixture, it was shaken until the pink colour disappear. After adding three drops of phenolphthalein indicator to the mixture, the solution was titrated again using 0.1N NaOH. The volume of the final titration was then recorded when the pink colour was appeared. The following formula was used to determine the degree of esterification [29].

$$\text{Degree of Esterification (\%)} = \frac{\text{Final Volume (ml)}}{\{\text{Initial volume(ml)} + \text{Final volume(ml)}\}} \times 100$$

Solubility Holding Capacity

In 5 ml of a solvent, 250 mg of pectin were added, in order to measure the solubility of the pectin. Kept the solutions aside for 2 minutes to settle, their solubility was assessed [12].

Holding Capacity of Solvent

1 M NaOH was mixed with 1 g of pectin. The mixture went through a centrifuge at 3500 rpm for 30 minutes after it was permitted to stand for two hours. Further, the pectin was weighed, and the following formula was used for calculation [12].

$$\text{SHC} = \frac{X - Y}{Y} \times 100$$

Where, X – Wet weight of pectin
Y – Dry weight of pectin

Water holding Capacity

200 mg of pectin was combined with 10 mL of distilled water and vortexed for 1 minute. After it was centrifuged at 3000 rpm for 30 minutes, the supernatants were then eliminated. The remaining pellets were weighed [10].

FTIR characterization

Pectin is a complex polymer containing hydroxyl groups, carboxyl groups (both esterified and non-esterified), and other functional groups. The FTIR characterization of pectin is carried out in order to ascertain the pectin's chemical and functional properties, as well as its carboxyl and hydroxyl groups in the structure and polygalacturonic acid content. The purpose of FTIR is to pinpoint the precise functional groups found in pectin molecules. Through distinctive absorption bands, FTIR can reveal whether these functional groups are present. The degree of esterification (DE) of pectin, a critical factor in the characterization of pectin, is one of the details about the molecular structure of pectin that FTIR can reveal. DE shows how much pectin's carboxyl groups are esterified with methyl groups, which influences the gelling characteristics of the substance [16].

RESULTS

Pectin yield

According to the formula, the pectin yield obtained from muskmelon, watermelon and banana were 8%, 7.5% and 6% which are tabulated (Table 1). From the tabulated value the muskmelon has the highest pectin yield (Fig 1).

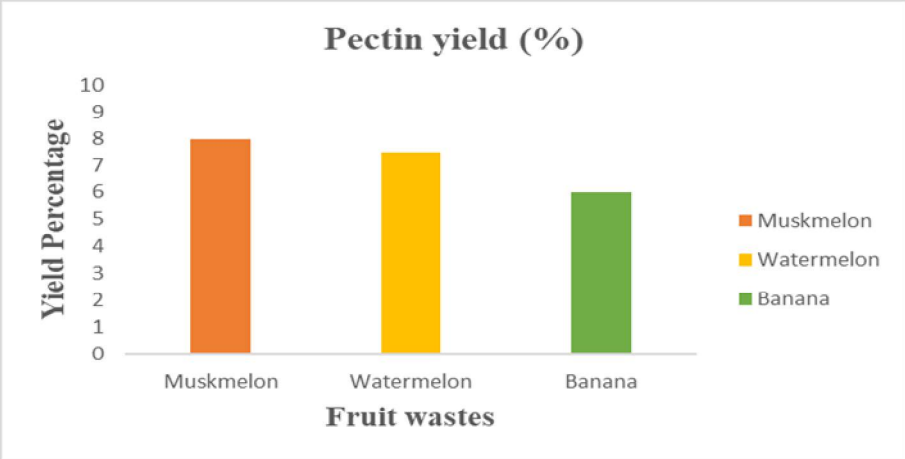

Fig 1: Pectin yield (%)

Determination of equivalent weight

Using the formula, the equivalent weight of the pectin was determined in muskmelon, watermelon and banana were 80(g/mol), 75(g/mol) and 60(g/mol) which are tabulated (Table 1), which describes that muskmelon has the high equivalent weight (Fig 2).

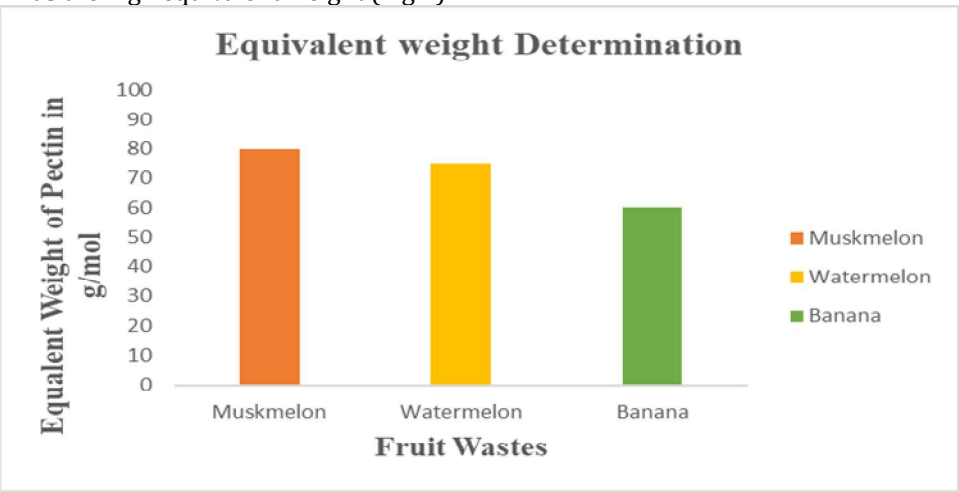

Fig 2: Equivalent weight determination

Methoxy content

In this work, the methoxy content were determined in muskmelon, watermelon and banana were 24.128%, 25.833% and 32.292% which are tabulated (Table 1). According to the tabulated value, the banana has the highest methoxy content (Fig 3A, 3B & 3C).

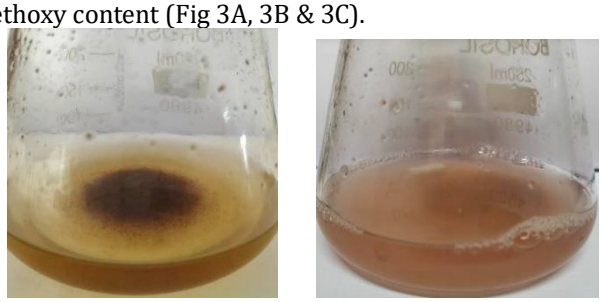

Fig 3A: Methoxy content determination of muskmelon peels

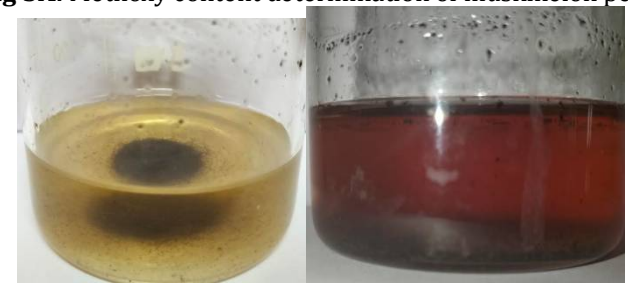

Fig 3B: Methoxy content determination of watermelon peels

Fig 3C: Methoxy content determination of banana peels

Determination of moisture content:

Moisture content was determined in various pectin like muskmelon, watermelon and banana were 59.1%, 71.42% and 19% which are tabulated (Table 1) which describes that watermelon has the highest moisture content rate (Fig 4).

Fig 4: Moisture content determination

Determination of Ash content:

The ash content was determined in various fruit peel pectin like muskmelon, watermelon and banana were 6%, 5.6% and 5% which are tabulated (Table 1), which shows that muskmelon exhibits highest ash content (Fig 5).

Fig 5: Ash content determination

Alkalinity test:

Using the formula, the alkalinity of pectin from different fruit peels like muskmelon, watermelon and banana were 75%, 60% and 66% which are tabulated (Table 1), shows that muskmelon show high alkalinity level (Fig 6).

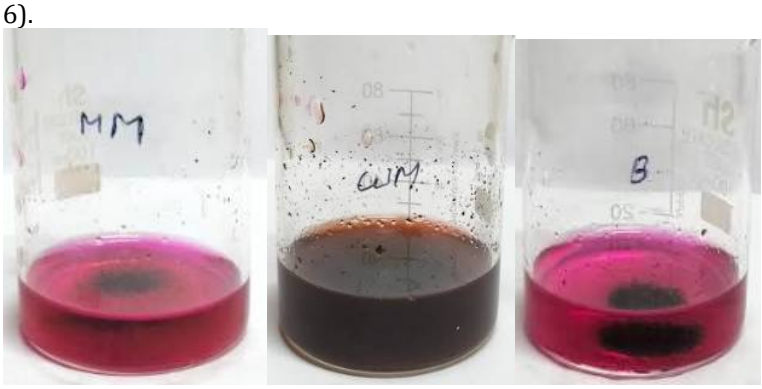

Fig 6: Alkalinity test determination

Degree of esterification:

Degree of esterification in different fruit peel pectin like muskmelon, watermelon and banana was 97.03%, 81.50% and 98.8% which are tabulated(Table 1). In the table, banana exhibit high level of Degree of esterification (Fig 7).

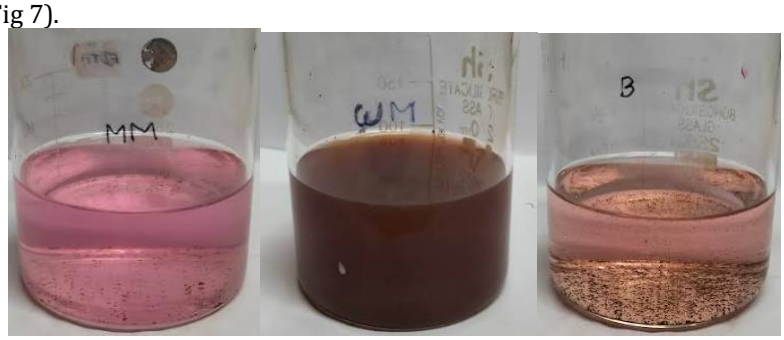

Fig 7: Degree of Esterification

Table 1: Physiochemical properties of pectin

Physiochemical properties of pectin	Muskmelon	Watermelon	Banana
Pectin yield (%)	8	7.5	6
Equivalent weight Determination (g/ mol)	80	75	60
Methoxy content (%)	24.128	25.833	32.292
Moisture Content (%)	59.1	71.42	19
Ash content (%)	6	5.6	5
Alkalinity (%)	75	60	66
Degree of esterification (%)	97.03	81.50	98.8
Water Holding Capacity (g water/ g ample)	0.4	0.68	1.4

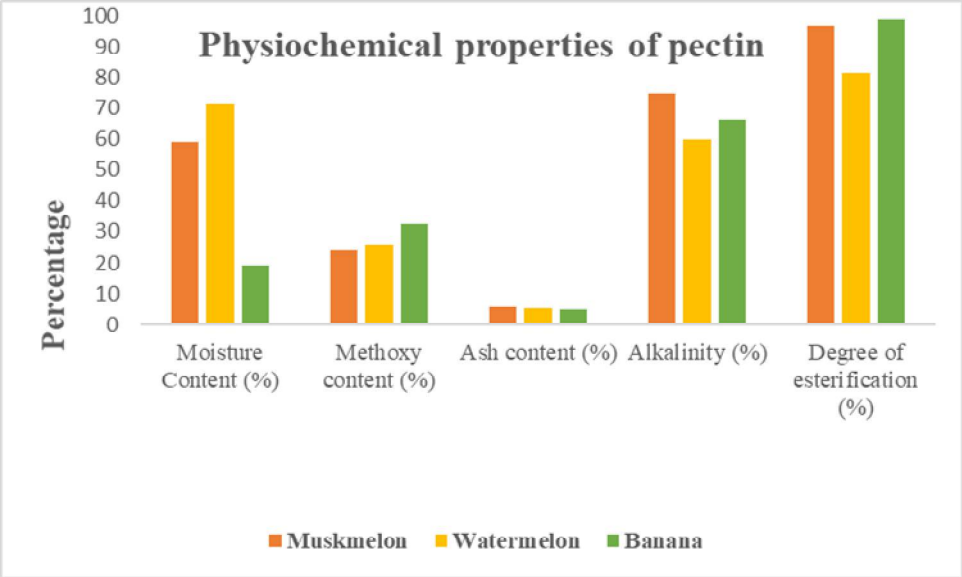

Fig 8: Physiochemical properties of pectin

Solubility Holding Capacity

Solubility Holding Capacity of pectin were done and founded that muskmelon, watermelon and banana are soluble in 0.1 M NaOH (Fig 9).

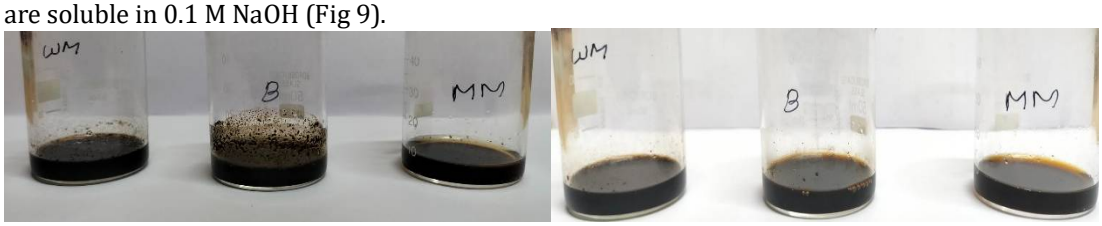

Fig 9: Solubility Holding Capacity

Solvent Holding Capacity:

The solvent holding capacity was determined and observed that banana has high solvent holding capacity (Fig 10).

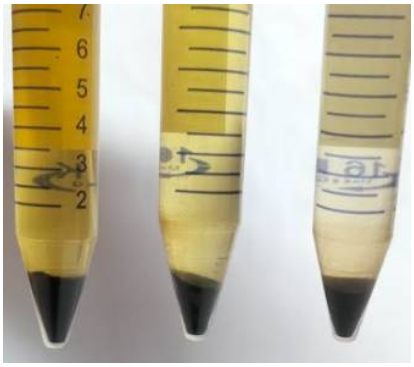

Fig 10: Solvent Holding Capacity

Water Holding Capacity:

According to the formula, the water holding capacity of different fruit peels like muskmelon, watermelon and pectin was 0.4, 0.68 and 1.4 (g water/ g sample) which are tabulated (Table 1). It denotes that banana has high water holding capacity (Fig 11 & 11A).

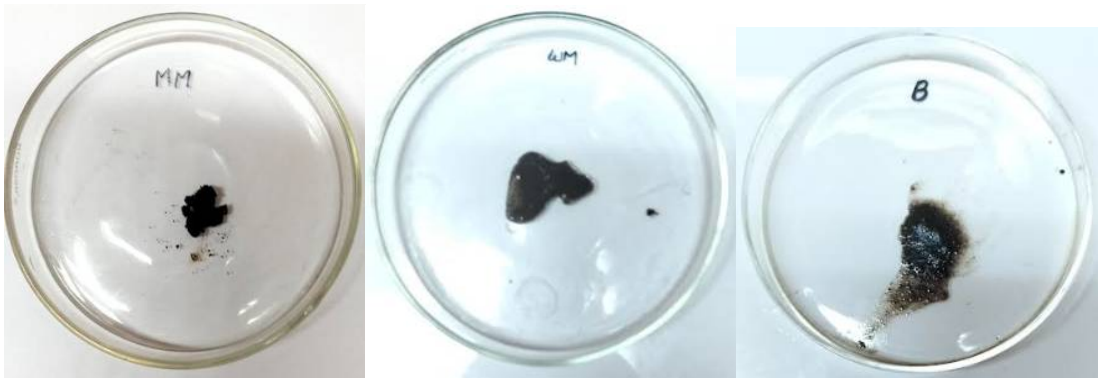

Fig 11: Water holding capacity

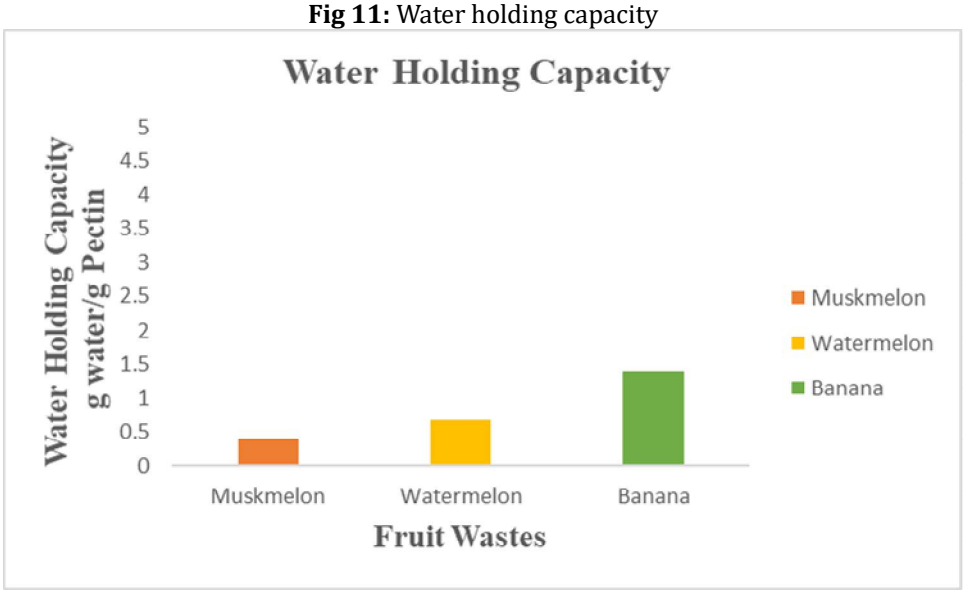

Fig 11A: Water holding capacity

Characterization

	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	468.67	92.433	7.636	495.67	459.99	0.657	0.634
2	1011.59	98.809	0.947	1061.74	982.66	0.216	0.179
3	1104.17	99.023	0.917	1132.14	1061.74	0.158	0.164
4	1627.81	96.598	2.852	1688.56	1560.3	1.171	0.85
5	1731.96	97.662	1.703	1781.14	1701.1	0.556	0.315
6	2332.74	65.669	3.617	2339.49	2236.31	8.268	-0.691
7	2381.92	59.709	39.804	2510.18	2361.67	7.7	7.39
8	2923.88	98.085	0.884	2954.74	2880.49	0.439	0.113
9	3436.91	91.686	0.478	3448.49	3175.58	5.171	-0.226

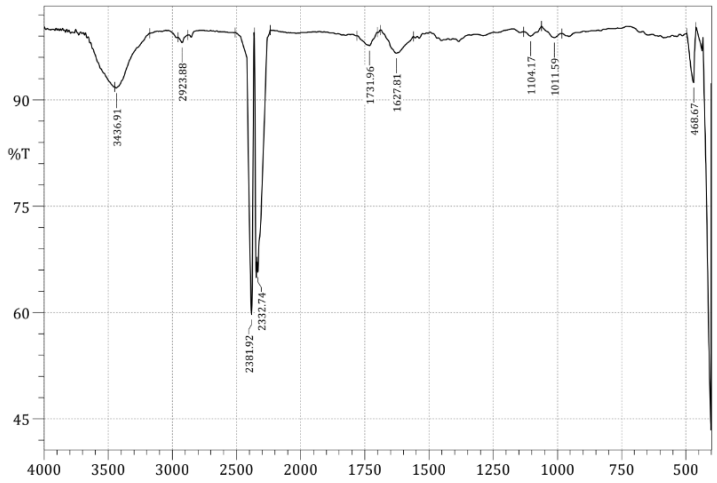

Fig 12: FTIR Characterization of pectin

In this investigation, the extracted pectin's highest peak value was found to be 2381.92 nm, indicating that the pectin obtained under the extraction conditions exhibited both chemical functional properties and a high concentration of polygalacturonic acid (Fig 12).

DISCUSSION

All over the world, fruit wastes are dumped into environment which has a high amount of nutrient content like carbohydrates, fiber, proteins and phytochemicals mainly phenolic compounds [17]. From this waste we had extracted pectin by solvent precipitation. Fruit waste are collected from nearby places and pectin are extracted from fruit peel waste like muskmelon, watermelon and banana. Various fruit peels are mixed with distilled water and boiled. The solution was then filtered and ethanol were added for the precipitation. After precipitation process, centrifuge the extract solution at 5000 rpm for 10 minutes. The supernatant was removed and pellet were obtained. Dry the pellet in hot plate until the removal of moisture content and dry pectin is obtained. The extracted pectin was then characterized and its physiochemical properties were analysed. The term "pectin yield percentage" describes the percentage of pectin that can be extracted from a raw material, usually fruits, as a percentage of the material's overall weight. The fruit type, level of ripeness, and extraction technique are some of the variables that can affect the pectin yield percentage [21]. The equivalent weight, representing the total galacturonic acid content, varies based on pH and extraction solvent. It is influenced by the presence of free acids, with lower values attributed to pectin polymerization at lower pH levels [19]. Neutral solution is obtained from the equivalent weight determination. The methoxy content is then determined using this neutral solution. Many characteristics of pectin, including its sensitivity to metal ions, setting time, and gel strength, are significantly influenced by its methoxyl content [30]. The extraction process and the pectin's source are two variables that affect this parameter. Temperature, crystallization, molecular size, and composition all affect how much water pectin absorbs. Pectin-solvent interactions are impacted by variations in moisture content (MC), which is dependent on solvent conditions. Microbial growth is promoted by higher MC. Powdered pectin with low MC is perfect for industrial use and long-term storage. Pectin's ash content serves as a purity indicator; a higher ash content denotes more impurities. A low ash content (less than 10% is ideal for high-quality gels) encourages better gel formation, so pectin of superior quality should have as little ash as possible [12]. The alkalinity test for pectin is a method used to determine the degree of methoxylation in pectin. The degree of methoxylation refers to the number of methoxy (–OCH3) groups present on the galacturonic acid units within the pectin molecule. This parameter is important for understanding and controlling the gelling properties of pectin [5]. Higher DE in pectin resulted in lower charge density and electrostatic interaction. Viscosity is increased when pectin with a higher charge density combines with cations through electrostatic interactions [30]. The term "solubility holding capacity" describes pectin's capacity to dissolve or swell in water and retain a specific volume of solute. pH, temperature, and the presence of other substances are some of the variables that affect pectin's solubility. A substance's (like pectin's) solvent holding capacity (SHC) is a measurement of its capacity to absorb and retain a specific volume of solvent, usually water. SHC plays a vital role in the pectin context as it affects the material's functionality and performance in a variety of applications, chiefly in the food and pharmaceutical industries [12]. Yogurt benefits from pectin's high water holding capacity (WHC), which enhances textural qualities and solves syneresis problems. The amount of galacturonic acid (GalA), the quantity of free hydroxyl groups, porosity, particle size, and molecular structure are some of the factors that affect WHC. By making the most of these variables, pectin can hold onto more water, which improves yogurt texture and decreases syneresis [10]. FTIR spectroscopy for characterizing pectin typically involves the measurement of infrared wavelengths in the range of approximately 400 to 4000 cm^{-1}. This range covers the midinfrared region and is suitable for analyzing the functional groups and chemical bonds present in pectin. Several chemical bond vibrational modes, including O-H (Hydroxyl group), C-H (Methine group), C=O (Ketone group), C-O (Carbonyl group), and others, can be seen and utilized to describe the structure and makeup of pectin in this spectral range. It is important to note that the specific range may vary significantly depending on the equipment and sample preparation, but the range listed above is a typical place to start for pectin FTIR analysis. The bands that form between 1623 and 1428 cm^{-1} show that the pectin is rich in polysaccharides, carboxyl groups, and hydroxyl groups [16]. These properties were analysed and shows that pectin extracted from the banana peels shows high degree of esterification, high methoxy content and low ash content compared to the muskmelon and watermelon peels. But also the pectin extracted from both muskmelon and watermelon peels exhibits desirable methoxy content, degree of esterification and low ash content which can be commercially used as the high quality pectin. The pectin extracted from fruit peel waste replaced as a substitute of gelatin and

commercial pectin. Further, this extracted pectin can be used as a thickening agent in food and pharmaceutical industry.

CONCLUSION

In this investigation pectin was extracted from easily available fruit wastes like muskmelon, watermelon and banana fruit peels. Since the extracted pectin fulfils the specifications for use as an additive in a variety of food and pharmaceutical industries, it can be used in new applications because it is a better alternative for commercial pectin derived from various plant sources. It was characterized and observed through FTIR and various physiochemical properties. Thus, extracting pectin from muskmelon, watermelon and banana fruit peels has the potential to valorise agricultural waste and contribute to the circular economy. Through the experimental work high yield percentage of pectin content was obtained from muskmelon and watermelon fruit peels than banana peels. Yet further research must be conducted to assess the utility and economic potential of extracting pectin from the investigated fruit peels and to develop anti-diabetic gummies for people with diabetes mellitus by utilizing the extracted pectin.

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