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ABSTRACT

The utilization of Philippine carabao mango (*Mangifera indica*) peels as potential source of pharmaceutical grade pectin was assessed. The physico-chemical properties of produced pectin were analyzed and compared with the United States Pharmacopeia (USP) specifications for pharmaceutical grade pectin.

This research successfully produced pectin from carabao mango peels that conformed to USP standard. The established extraction process was solubilization of mango peels at 100^{o}C for 60 minutes with acidified water at pH 2. The average percent yield of pectin was 21.65 percent (dry weight basis). The produced pectin has methoxyl content of 12.65 to 12.84 percent, galacturonic acid content of 92.82 to 98.65 percent and degree of esterification of 76 to 79.

The total dietary fiber and sugar contents were 77.4 percent and 4.8 percent, respectively. It is brownish to grayish, with arsenic and lead contents of 0.0435µg/g and 3.27µg/g, respectively. No Salmonella sp. was detected.

Cost analysis revealed that the production cost for USP grade pectin from mango peels at a laboratory scale set-up was estimated at P5,667.51/kg. Compared with the landed cost of imported pectin at P27,122.56/kg (Department of Trade and Industry, 2011), the production of pectin out of mango peels in the country, therefore, is technically and economically feasible. The total volume of mango peels needed to produce the total volume of the country's pectin importation in 2011 amounted to 94,849 kg which was only two percent of the total mango peels wasted at the processors level.

Hence, local production of pectin from mango peels at a commercial scale has great potential. It will help in creating job opportunities to wide sectors and in saving the country's dollar reserves. In addition, the utilization of voluminous solid wastes from mango processing plants is environment-friendly, thus, it contributes in saving the earth from depletion which is a major global concern.

INTRODUCTION

Pectin is a group of complex carbohydrate derivatives mainly present within the primary cell wall and intercellular regions of plants (Voragen et al., 1995). They usually form a gelatinous substance when combined with sugar and acids.

Pectin has many applications as functional ingredient in food science, nutrition, cosmetics and pharmacy. It is used in pastry glazes and as stabilizer in drinkable yogurts and blends of milk and fruit juices (May, 1990). Pectin is also being used as a texturizing fat replacer to mimic the mouth-feel of lipids in low-calorie foods. Pectin has also been investigated for its usefulness in the pharmaceutical industry. It has been considered in the class of dietary fiber known to have a positive effect on digestive processes and it helps lower cholesterol. It is also utilized to stabilize liquid pharmaceutical emulsions and suspensions and increases the viscosity of certain drug preparations (Braddock, 1999).

Philippines relies heavily on imported pectin due to the absence of a viable technology to produce it locally. In 2011, the Philippines' total pectin importation from various origins reached 94,848.93 kg with total custom value of US$ 52,383,487 or P2.2 billion (DTI, 2008). These were mainly used by the food processing, cosmetics and pharmaceutical industries as thickening, gelling and stabilizing agents.

Citrus peel and apple pomace are the major raw materials for the production of commercially available pectin. The Industrial Technology Development Institute (ITDI) of the Department of Science and Technology (DOST) has produced USP grade pectin from calamansi peels at a laboratory scale. Pectin recovery in calamansi peels is around 10 to 14 percent (Torres et al, ITDI). However, the main constraint in the local production of pectin from calamansi peel is the limited volume of calamansi peels at the processor's level (personal communication, R. Torres, 2011). The total production volume of calamansi was 182,532 metric tons only (BAS, 2011).

There are reports that mango peels are potential source of pectin but has not yet been explored as alternative commercial pectin source even in other countries. Mango peel was found to contain polyphenols and dietary fiber (Larrauri et al, 1996) and could be a very useful raw material for the extraction of pectin . Pectin recovery from mango peels is 20.8 percent as reported by Sudhakar et al (1999) and 39 percent by Flores-Lopez et al., (2003).

The Philippines ranked ninth among the top major mango producing countries in the world with total volume of production of 825,676 metric tons with a total value of US$494.72 million or about P20.78 billion (FAO Stat, 2012). Of the total volume of production, 80 percent are carabao mango (BAS, 2011) and out of this proportion, 75 percent are consumed fresh and 25 percent are processed into various products such as dried mangoes and mango puree (AMAD-Davao Region, 2011).

Mango peels constitute about 15 to 20 percent of the total weight of the fruit (Beerh et al, 1976). As such, a total of around 24.7 to 33.0 million kg of mango peels at the processors level alone are wasted annually considering that these are not utilized for any commercial or value adding purposes. Moreover, these wastes mango peels present serious disposal problems as shown in the pictures below.

OBJECTIVES

General:

To develop an efficient extraction process for the production of high grade pectin isolated from Philippine carabao mango peels

Specific:

1. To establish the extraction process that will yield the highest obtainable pectin from Philippine carabao mango peels;
2. To characterize the physico-chemical properties of pectin isolated from Philippine carabao mango peels and compare with the USP specifications; and
3. To conduct cost analysis in producing pectin from Philippine carabao mango peels.

REVIEW OF LITERATURE

Pectins are major constituent of plant cell walls and greatly affect the quality of many plant-derived food products (Anthon and Barret, 2008). It is one of the most versatile stabilizers available. Pectins have many applications in food science, nutrition, cosmetics and pharmacy (Koubala et al, 2008). Its gelling, thickening and stabilizing attributes makes it an essential additive in the production of many food products (Sirisakulwat, 2008). Recent studies, however, reported its potential role in human health. Clinical data showed that pectin demonstrated a statistically significant increased in prostate-specific antigen (Pienta et al, 1995). It was also shown to exhibit chelating effects which significantly increased the urinary excretion of arsenic, cadmium and lead in adults after six days of administration (Eliaz et al, 2006). Pectin was used in the management of diarrhea for many years by improving stool quality, thereby reducing the amount of oral replacement solution and intravenous fluids for hydration needed thus shortening the duration of illness (Rabbani et al, 2001). Waterhaus (2000) reported that pectin reduces the amount of food and acid concentration reaching the esophagus thus reducing heartburn. Also, a new form of pectin called modified citrus pectin has been shown to prevent spontaneous prostate cancer metastasis by inhibiting the cancer cells from adhering to other cells in the body.

Pure pectin is essentially a soluble dietary fiber (May, 1990). Pectin is categorized as a soluble dietary fiber since it goes through the small intestine more or less intact, thereby absorbing cholesterol. The US FDA recognizes pectin as generally recognized as safe (GRAS) substance. The joint FAO /WHO Committee on Food Additives have not set numerical average daily intake (ADI) for pectin, so it is categorized as very safe to humans (IPPA, 2001).

This wide range of pectin applications explain the need for many different types of commercial pectins which are sold according to their application. Pectin with more than 50 percent of the esterified acid units is classified as high methyl ester (HM) pectin. Low methyl ester (LM) pectin which is produced through modification of the extraction process or continued acid treatment has less than 50 percent methyl ester groups. It is used to make low sugar jams and many different fruit preparations for use in the food industry. Amidated pectin, on the other hand, is produced through treatment of some pectin with ammonia. It has particular advantage in some applications such as stopping the milk protein in yoghurt from curdling with heat so heat treated (UHT) long life yoghurt drinks can be made. (IPPA, 2001).

According to May (1990), pure pectin in principle, may be isolated in many ways. The most commonly used method is to mix the concentrated extract with an organic solvent in which pectin is insoluble, but which will permit many of the impurities to remain in solution. International food standards permit the use of only methanol, ethanol, isopropanol as the organic solvents for pectin extraction. In this process, the clarified pectin extract is concentrated to about 2 percent pectin, and mixed with sufficient alcohol to give a precipitate firm enough to be handled with the separation technology chosen by the manufacturer concerned, which may be either filtration or centrifugation. Pectin is separated as completely as possible from the mother liquor, and washed once or several times with aqueous alcohol to remove salts and other impurities. The washing liquor may include sufficient food grade alkali to adjust the pH of the final pectic solution to the desired range. Afterwards, the isolated pectin is dried and pulverized to a fine powder.

Commercial sources of pectin are mostly citrus peel and apple pomace. The use of mango peels as source of pectin was proposed by several authors. Nwanekezi et al., (1995) reported that mango pectin had the highest methoxyl ester content and was the purest, with an anhydrogalacturonic acid content of 81.6 percent. Bernardini et al, (2005) reported that the mango peels of the cultivars Manila and Tommy Atkins appeared to be the most promising cultivars with respect to pectin content and quality. However, the Manila mango that was the subject of his investigation came from Thailand which basically has different cultural practices/management and different soil properties and characteristics. Many studies have shown that the amount, structure and biochemical characteristics of pectin depend on the plant source and cultivars aside from the extraction procedures (Koubala et al, 2008). Sirisakulwat et al, (2008) reported that mango has been deemed a promising, but not yet exploited, alternative pectin source.

Mango is the country's national fruit and is considered as one of the finest in the world. It is the third most important crop of the country based on export volume and value, next to banana and pineapple. About a quarter of the total mango production is processed into various product forms such as mango puree, mango juice, dried mangoes, mango concentrates, and many more. Large volume of wastes are produced in mango processing plants which can be utilized for production of valuable product like pectin. By-products of industrial mango processing may amount to 35 to 60 percent of the total fruit weight (Larrauri et al, 1996). Mango peels contributes about 15 to 20 percent to the fruit weight (Ajila et al, 2007). Because these present serious disposal problems, ways for their valuable utilization have been explored. While the utilization of the mango kernels as a source of fat, natural oxidants, starch, flour and feed, respectively, has been investigated by many researchers, studies on peels are scarce though their use for the production of biogas or dietary fiber with high antioxidant activity has been described in the past.

As of 2006, based on the listing of companies registered with the Bureau of Investment (BOI), there are approximately 17 mango processors in Luzon, 11 in Visayas, and four in Mindanao (http://sme12.ph/sme12/index.php) indicating that substantial volume of mango peels are generated throughout the Philippine archipelago.

CONCEPTUAL FRAMEWORK

This project used the following conceptul framework:

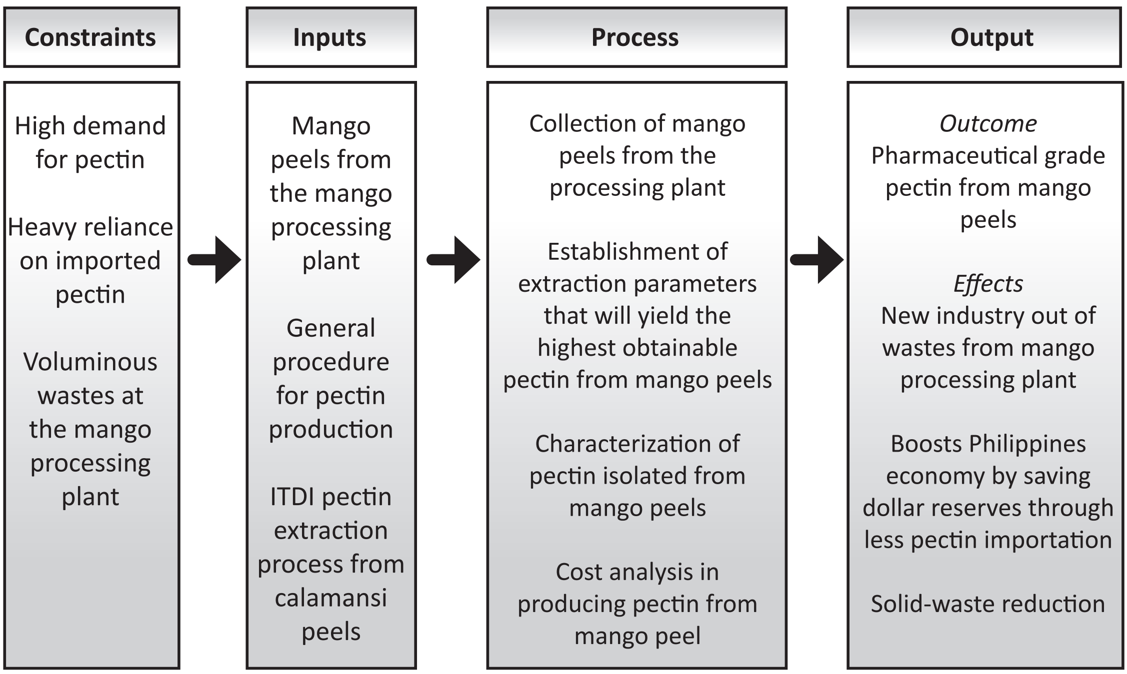

Figure 1. Project Conceptual Framework

METHODOLOGY

Sample History and Collection

Fresh carabao mango fruit wastes were collected from a commercial fruit processing plant in Malolos, Bulacan from April to May 2011. The company processes various mango products for local consumption and export. Two kinds of mango wastes were produced at the plant, either from the aseptic processing of mango puree wherein the fruits were squeezed out mechanically to extract the mango juice, or from the dried fruit processing wherein the fruits were cut into halves and peeled manually.

During processing, the mango wastes go directly to the hired dump truck through a conveyor. The truck hired at P4,500 per load can accommodate 10 tons of wastes. During off season (March and June), two truckloads of wastes are produced in the plant per day. During peak season (April and May), the plant operates 24 hours for two months and produces 10 truckloads of wastes per day of operation. The wastes are being dumped as landfill in a lot sourced out by the truck owner.

Huge volume of mango fruit wastes were collected and were immediately brought to PHilMech laboratory. The peels were separated from the seeds and were washed with tap water, blanched at 90°C for 10 minutes, placed in clean sampling bags, and stored in chest freezer prior to pectin extraction to prevent breakdown of the peels and microbial attack.

Figure 2. Mango peels collected from processing plant

Figure 3. Mango peels stored in freezer

Extraction of Pectin from Mango Peels

The mango peel samples were withdrawn from the freezer, thawed, and washed to eliminate fruit sugar that was retained in the peel. After washing, the peels were drained, then processed for extraction as fresh or dried to differentiate pectin yield between fresh and dried mango peels. Dried peels were pulverized with blender and other portions were chipped prior to pectin extraction. This was done to differentiate the effect of size of dried peels on pectin yield.

Figure 4. Mango peels collected from processing plant

Figure 5. Mango peels stored in freezer

The mango peels were subjected to hydrolysis by treating the raw materials with distilled water acidified at different pH levels (1.5, 2, 2.5), temperature (70^{o}C, 80^{o}C, 90^{o}C, 100^{o}C) and heating time (30, 60, 120 minutes) to establish the extraction condition that will give the highest pectin yield. The resulting extract was cooled to 60^{o}C and filtered to remove solids/insoluble residues to obtain the pectic liquor. Extraction was done twice. The pectic liquor was precipitated with 95 percent ethyl alcohol. The mixture was left overnight to allow complete precipitation of pectin. The fibrous coagulum (pectin) was recovered from the liquor by passing this through silk cloth. The pectin obtained was purified with successive washings with the recovered ethyl alcohol and a final rinse was done with fresh 95 percent ethyl alcohol. The fibrous pectin was ripped up, dried at a temperature not more than 60^{o}C, pulverized to a fine powder, sieved and stored in clean, dry air-tight container. Percent recovery of pectin from fresh or dried mango peels using different parameters was determined by computing the ratio of pectin produced over the amount of the raw materials utilized.

$$\%\ \text{Pectin recovery} = \frac{\text{Weight of pectin}}{\text{Weight of mango peels}} \times 100$$

Characterization of Pectin

The test for pectin identity and physico-chemical properties such as methoxyl content, galacturonic acid and degree of esterification were determined using the standard procedure of United States Pharmacopeia, 1980. The viscosity, gel grade, gel strength, setting time and temperature were determined following the methods described by Ranganna (1986). In addition, other characteristics such as dietary fiber, sugar content, moisture, ash content, arsenic and lead content were evaluated following the AOAC methods of analysis. Microbial load was analyzed following the standard microbiological assay as described by Pitt and Hocking, (1997) for fungi and following the Biolog identification system for bacteria.

Statistical Analysis

All analyses were done with two to three replications. The obtained data were analyzed using analysis of variance to determine the significant differences among extraction parameters. The comparison between the mean values were tested using Duncan's multiple range test at five percent level of significance.

Cost Analysis

The total costs involved to produce pectin utilizing mango peels at the laboratory was computed. Two major components were considered to come up with cost analysis, the variable and fixed costs. The variable components comprise all the direct costs related to pectin production (i.e. mango peel, ethanol, distilled water, HCl, satin cloth, electric consumption, etc.), labor cost (manpower to wash, dry, pulverize the mango peel, extraction of pectin, etc). The fixed components are the indirect costs known as overhead or depreciation costs of equipment (oven, grinder/blender, stove, pail/container, cooking casserole, dipper, etc). Since ethanol was reusable and can be recovered (93% as reported by Sudhakar, 1999), 70 percent recovery was assumed and inputted in the computation of cost of pectin production.

RESULTS AND DISCUSSION

Pectin Recovery

Recovery of pectin from fresh mango peels was very low or minimal even when the temperature and peel to extractant ratio were varied as shown in Table 1. The maximum pectin yield obtained was 1.7 percent only. So, further trials using fresh mango peels were aborted for practical reasons.

Table 1. Percent yield of pectin from fresh mango peels

Peel: Extractant Ratio	**Extraction temperature**	
	90^{0}C	100^{0}C
1:4	0.85	1.24
1:6	1.35	1.49
1:8	1.57	1.7

Dried mango peels with different sizes were evaluated for the isolation of pectin and the results were shown in Table 2. It was observed that the size of the dried mango peels as raw material affect the recovery of pectin. Higher pectin yield was obtained when the dried mango peels were pulverized with a yield of 20.24 percent compared with the chipped dried mango peel which gave a yield of 16.35 percent only. This was due to the greater chance of the extracting solvent to penetrate into the finer tissue of the mango peels and come in contact with the pectic substances present on or in between the cell walls thereby converting the insoluble pectic substance into soluble pectin (Nanji and

Norman as reported by Sudhakar and Maini, 1999). Therefore, pulverized dried mango peels were utilized in succeeding studies.

Table 2. Percent yield of pectin from dried mango peels

Sample	Yield, %
Chipped Mango Peel	16.35
Pulverized Mango Peel	20.24

Pectin extraction from mango peels could not be recovered in a single extraction so a second extraction was found necessary to recover most of the pectin content present in the peel using peel to extractant/solvent ratio of 1:10. Though the third extraction yielded around 1.5 percent pectin (Table 3), this was considered uneconomical considering the volume of solvent required for isolation and purification. Many researchers also found that two extractions each for one hour was enough to recover most of the pectin from the peels of fruits (Pruthi et al., 1960; Agarwal and Pruthi, 1968).

Table 3. Percent yield of pectin from dried mango peels per extraction

Extraction	Yield, %
First	14.64
Second	5.49
Third	1.56

Effect of Extraction time, Temperature and pH

Variable amount of pectin were obtained from mango peels at varying pH, temperature and extraction time as indicated in Table 4. This observation was in agreement with those noted by several researchers who reported that pectin has different compositions and yield depending upon many factors, and changes in pectin yield was mainly affected by the extraction process (Hussain et al., 1991; Rehman, et al., 2004). Acidity of the solution played a significant role in the extraction of pectin. Results of statistical analysis showed that the pectin yield increased when the pH was increased from 1.5 to 2.0. However, increasing further the pH to 2.5 did not cause further increased in the yield primarily due to the breakdown of pectic substance at higher pH. This observation implied that pH 2.0 is the best pH for pectin extraction from pulverized dried mango peel.

Table 4. Percent yield of pectin from dried mango peels at different processing parameters of temperature, pH and extraction time.

Extraction time, °C	pH 1.5			pH 2.0			pH 2.5		
	30 min	60 min	120 min	30 min	60 min	120 min	30 min	60 min	120 min
70	6.62^{e}	13.04^{cd}	13.00^{cd}	10.74^{de}	13.24^{cd}	9.47^{e}	3.97^{e}	5.51^{d}	5.33^{d}
80	11.74^{d}	16.71^{a}	16.03^{ab}	12.53^{cde}	13.18^{cd}	15.14^{bc}	5.47^{d}	6.88^{c}	6.58^{cd}
90	14.39^{bc}	13.65^{cd}	16.18^{ab}	16.89^{b}	15.26^{bc}	17.65b	5.70^{cd}	5.46^{d}	9.82^{b}
100	17.66^{a}	17.06^{a}	16.01^{ab}	14.16^{bcd}	21.65^{a}	15.80^{bc}	10.39^{ab}	9.83^{b}	11.15^{a}

Values are expressed on dry weight basis. Any means having the same manuscript are not significantly different at 5% level

Generally, the yield of pectin increased significantly with the increase in time of extraction from 30 to 60 minutes as shown in Table 5. Highest pectin yield was obtained by extracting the dried mango peels for 60 minutes which gave 21.65 percent pectin recovery. Decrease in pectin yield was noted when the dried mango peels were heated at prolonged time, 120 minutes in the case of the present study. This observation was consistent with the findings of other workers who reported that prolonged extraction adversely affect the yield of pectin and this was attributed to the breakdown of pectic molecules as observed by Rehman et al., (2004); Chang et al., (1994) and Turmucin et al., (1983).

The extraction temperature set at 100°C produced highest yield of pectin in most of the trials conducted as shown in Table 5. The data revealed that extraction temperature is a function of pectin yield. Since there was a report of the destructive effect of extraction period longer than one hour at 100°C on the quality of isolated pectin (Sudhakar and Maini, 2000), no further tests were done beyond this temperature limit.

Therefore, the optimum parameters established for pectin extraction from mango peels on dried basis were solubilization of the mango peels with acidified distilled water at pH 2.0 for 60 minutes at 100°C. Higher recovery of pectin was obtained in the present study compared with that obtained by Bernardini et al., (2005) with total yield of 17.6 percent only. On the other hand, Rehman (2004) also obtained a maximum yield of 21 percent good quality pectin from the mango peels.

Physico-Chemical Characteristics of Isolated Pectin

Identity of isolated pectin

The isolated mango pectin formed a stiff gel on cooling when heated with water on a steam bath. It also formed a translucent gelatinous precipitate when its 1 percent aqueous solution was treated with an equal volume of alcohol. This identification test differentiated pectin from most gums. The produced pectin, likewise, exhibited a transparent gel or semi-gel when its 1 percent aqueous solution was treated with potassium hydroxide solution and allowed to stand at room temperature. This test differentiated pectin from tragacanth. Furthermore, pectin produced a voluminous, colorless and gelatinous precipitate when the gel previously mentioned was further acidified with hydrochloric acid. This precipitate became white and flocculent due to the presence of pectic acid. The tests, therefore, confirmed that the isolated material from mango peels was really pectin.

Color of isolated pectin

Table 5 shows the color measurement data of apple pectin and mango peel pectin. Data indicated that the produced mango peel pectin is slightly darker (indicated by L* value) compared with apple pectin. The difference in color could be due to the difference in the natural color of apple and mango peel. Apple pomace itself is originally white while the mango peel is golden yellow (indicated by higher +b* value) which normally turned darker after drying. The color of mango peel pectin was still within the USP specification for color which is grayish to light brown.

Table 5. Color measurement data of apple pectin and mango peel pectin

Sample Description	L*	a*	b*
Apple Pectin	73.54 ± 0.25	+6.55 ± 0.22	+16.10 ± 0.29
Mango Peel Pectin	58.91 ± 0.33	+2.65 ± 0.02	+16.34 ± 0.01

Degree of esterification and galacturonic acid, methoxyl content and other characteristics

The physico-chemical properties of pectin produced from carabao mango peel met the standard specifications of USP, 1980 as shown in Table 6. The pectin that was produced from mango peels has a degree of esterification range of 76 to 79, galacturonic acid of 92.82 to 98.65 percent and methoxyl content of 12.65 to 12.84 percent which was 1.9 times higher than the minimum requirement of USP specification for methoxyl content. The produced pectin was categorized as high methoxyl pectin. Pectin is characterized as high methoxyl pectin if it contains more than 50 percent esterified galacturonic acid residues. As high methoxyl pectin, it is capable of forming gels in aqueous system with high contents of soluble solids and low pH value. High methoxyl pectins are attractive viscofiers for softdrinks. With this property, pectin builds a similar mouthfeel to that of fruit juices, and is therefore useful in juice drinks and in low calorie or diet drinks. In addition, high methoxyl pectins have the advantage of delivering very clean flavor release (Cargill Food Ingredients, 2012). Only pectins with more than 60 percent degree of esterification are usually employed in the food industry (Ptichkin et al., 2008). The mango peel pectin produced in the study met this requirement.

The produced pectin has a total ash content of 3.32 percent and acid-insoluble ash of 0.80 percent, basically lower than the maximum limit of USP grade which is 10 percent and 1 percent, respectively. Loss on drying was determined at 8 percent. The total soluble solids was 0.40 percent. Mango peel pectin was slightly acidic with pH equal to 4.17

percent. These results denote the purity and high quality of the produced pectin.

Viscosity of mango peel pectin

The viscosity of mango peels pectin was measured as a function of speed in rpm and compared to the viscosity of the corresponding high grade apple pectin product from Sigma. For both samples, the graph (Figure 2) showed that speed is strongly correlated to viscosity. Regression analysis showed that both pectin behaved similarly with very close slope. Viscosity decreased with an increase on speed or shear rate. Mango peel pectin has a viscosity range of 92 to 180 cP at the speed of 20 to 100 rpm. Apple pectin, on the other hand has, a viscosity ranging from 78 to 150 cP at the same speed.

The data indicate that the mango peel pectin will give almost similar consistency or stickiness with that exhibited by high grade apple pectin indicating that the utilization of mango peel pectin in various applications will most likely display good results, thereby, making it a very good substitute for imported high grade apple pectin. Viscosity, solubility, and gelation are generally related. Factors that increase gel strength will increase the tendency to gel, decrease solubility, and increase viscosity, and vice versa (Marshal et al., 2007).

Table 6. Physico-chemical properties of pectin produced from mango peel as compared with the standard specifications of US Pharmacopeia.

Parameter	**Values**	
	Mango Peel Pectin	**USP Specification**
Degree of Esterification	76 - 79	Not specified
Methoxyl Content, %*	12.65 – 12.84	Not less than 6.7 %
Galacturonic Acid Content, %	92.82 – 98.65	Not less than 74%
Total Ash Content, %	3.32	Not more than 10%
Acid-insoluble Ash, %	0.80	Not more than 1%
Loss on Drying, %	8	Not more than 10%
Total Soluble Solids, %	0.40	Not specified

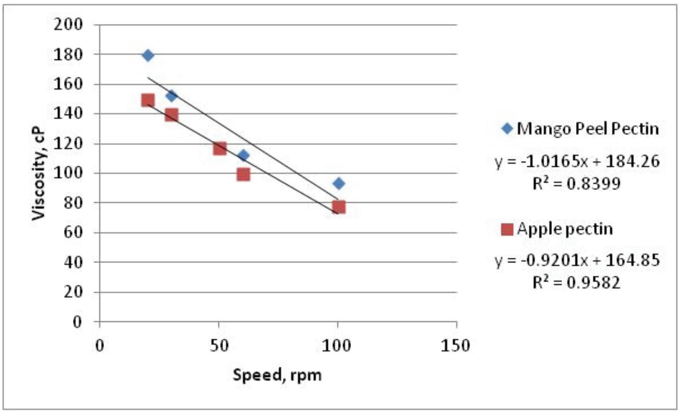

Figure 6. Plot of viscosity at different speed. Pectin solutions were measured with Cannon viscometer (model LV 2020) using spindle #64 at 25°C.

Pectin grade, gel strength, setting time and temperature

Grade of pectin means the weight of sugar with which one part by weight of pectin will, under suitable conditions, form a satisfactory jelly. This jelly, subjected to the usual finger testing, should have the proper texture, resilience and consistency.

Mango peel pectin formed gel of similar nature with high grade commercial apple pectin as shown in the picture below.

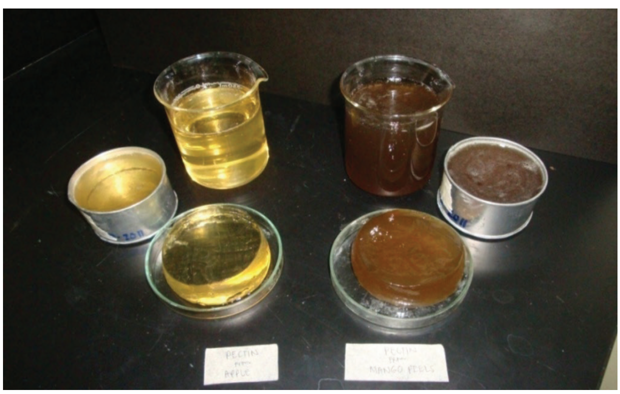

Figure 7. Apple pectin gel (left) and mango peel pectin gel (right)

The jellying properties obtained for both types of pectin are shown in Table 7. Analysis showed that the produced mango peel pectin has an assumed jelly grade of 140, slightly lower compared with the jelly grade of apple pectin of 150. This indicates that slightly larger amount of mango peel pectin is necessary to achieve similar jelly as that exhibited by apple pectin. The setting time determined for mango peel pectin and apple pectin were almost the same. Setting temperature of mango peel pectin was 75°C while that of apple pectin was 73°C. The gel strength obtained for both samples was the same, 0.074 N. These data revealed that the gelling properties of mango peel pectin that was produced in the present study were very close with those exhibited by high grade commercial apple pectin. The gel formed was firm as explained by high degree of esterification value that was obtained. Yapo (2009) reported that the positive gel forming capabilities of pectin jellies is associated with its high esterification value as displayed by the property of the produced pectin.

Table 7. Pectin grade, gel strength, setting time and temperature of mango and apple pectin

Sample	Assumed Jelly Grade	Setting Time (minutes)	Setting Temp. (°C)	Gel Strength (Newton)
Commercial Apple Pectin	150	3	73	0.074
Mango Peel Pectin	140	2-3	75	0.074

Sugar and total dietary fiber content

Analysis of dietary fiber showed that the produced pectin contained 77.4 percent total dietary fiber determined by using the enzymatic/gravimetric method. Pectin itself is a soluble fiber, containing 80 to 90 percent natural soluble fiber (Ptichkina et al., 2008). Soluble fiber which can be obtained from citrus pectin forms a gel as it passes through the digestive tract, preventing the absorption of various substances. This unique property has been thought to help fight many modern diseases such as diabetes, obesity, cardiovascular disease and arteriosclerosis (http://www.foodnavigator. com/news-by-product). From a nutritional point of view, pectin is an interesting dietary fiber. Although the USP specification does not indicate any minimum required value for this, high dietary fiber always indicate better functional attributes for certain food or additive.

Early research indicates that it has physico-chemical properties which may positively influence several biomarkers for cardio-vascular and digestive functions. It may act as cholesterol-lowering agent and preliminary research also showed that it can stimulate gut health (Cargill Food Ingredients, 2012). The present study also showed that the total dietary content in the isolated mango peels pectin is higher compared with the dietary fiber content of the corresponding weight of the dried mango peel which was found to contain 47.5 percent.

Likewise, the sugar content of the mango peel pectin is equivalent to 4.8 percent which is within the requirement of USP of not more than 20 percent.

Safety of isolated mango peel pectin from contaminants

The isolated mango peel pectin was found to contain 0.043 µg/g of arsenic. The allowable limit for arsenic of the USP grade pectin is not more than 3 µg/g. The lead content was 3.27 µg/g. The allowable limit for lead of the USP grade pectin is not more than 5 µg/g. Therefore, the pectin produced from mango peel does not contain heavy metals more than the safe limits.

Results of microbial analysis shown in Table 8 revealed the absence of Salmonella sp. in the produced pectin which affirmed its safety from harmful microbial contaminant.

The produced pectin from mango peels contained acceptable levels of chemicals. It is free from biological contaminants and therefore is very safe for human consumption.

Table 8. Level of safety of mango peel pectin

Parameter	Values	
	Mango Peel Pectin	**USP Specification**
Arsenic content, µg/g	0.0435 µg/g	3 µg/g
Lead content, µg/g	3.27 µg/g	5 µg/g
Microbial limit	Absence of Salmonella sp.	Absence of Salmonella sp.

Cost Analysis

The cost to produce 1kg of pectin at the laboratory scale was P5,667.51 as shown in Table 9. The average landed cost for 1kg USP grade apple pectin was P27,122.56 in 2011. Landed cost is the total cost of an internationally shipped item which includes the original cost of the item, all brokerage and logistics fees, complete shipping costs, customs duties, tariffs, taxes, insurance, currency conversion, crating costs, and handling fees. Compared with the landed cost of imported pectin, local production of mango peel pectin appeared very economical even if its market price is double its production cost to compensate for added expenses for packaging, distribution, profit, mark-up and others. This is a good indicator that local production of pectin from mango peel is a potential profitable venture.

Table 9. The list of expenditures incurred in the production of 1kg pectin

Fixed Cost	Amount, Php
Repair and Maintenance	101.54
Depreciation	371.41
Total Fixed Cost	**472.95**
Variable Cost	
Electric al consumption for:	***582.03***
Drying of fresh mango peels and isolated pectin	243.39
Pulverizing dried mango peel and isolated pectin	42.00
Storing fresh mango peels	43.20
Heating pulverized mango peel with acidified water	253.44
Chemicals & Laboratory Supplies	***5,884.35***
Ethanol	5,200.00
Distilled water	645.00
HCl	21.85
Satin cloth	17.5
Labor	**2,368.18**
Chemist: 1 x 2 days x 659.09/day	1,318.18
Laboratory aide: 1 x 350/day x 3 days	1,050.00
Total Variable Cost	**8,834.56**
Assuming 70% of ethanol will be recovered:	
TOTAL PRODUCTION COST	5,667.51

Figure 8. Apple pectin powder (left) and mango peel pectin powder (right)

CONCLUSION AND RECOMMENDATIONS

Pharmaceutical grade pectin with maximum yield of 21.65 percent was obtained from carabao mango peels by solubilization of the dried and pulverized mango peels with acidified water with pH 2 at 100^{o}C for 60 minutes. The produced mango peels pectin conformed to USP specifications for high grade pectin indicating that it is of superior quality.

The calculated cost for laboratory scale production of pectin from mango peels was P5,667.51/kg while the landed cost of imported pectin in 2011 was P27,122.56/kg (Department of Trade and Industry, 2011). Therefore, production of pectin from mango peels is both technically and economically feasible.

A pilot-scale production of pectin must be conducted to address the issues and concerns that will emanate in its commercial adoption.

With high cost of imported pectin, a country like the Philippines with abundant supply of quality raw materials may find it feasible to set-up factories in order to meet the domestic requirement for pectin. Aside from this, the Philippines can be a major pectin exporter if all the projected available mango peels in the country can be utilized for pectin production. Thus, utilization of mango peels for manufacturing of pectin will boost the country's economy through saving of dollar reserves because of less pectin importation, and job generation through the creation of a new industry thus helping alleviate poverty.

Moreover, it would have a very high impact to the environment through solid wastes reduction by converting them into a valuable industrial product, thereby saving our planet earth from depletion.

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About PHilMech

The Philippine Center for Postharvest Development and Mechanization, known then as the National Postharvest Institute for Research and Extension (NAPHIRE), was created on May 24,1978 through Presidential Decree 1380 to spearhead the development of the country's postharvest industry.

As a subsidiary of the National Grains Authority in 1980, the agency's powers and functions were expanded in line with the conversion of NGA to the National Food Authority.

In 1986, PHilMech moved to its new home at the Central Luzon State University compound in Muñoz, Nueva Ecija.

The agency was transformed from a government corporation intoa regular agency through Executive Order 494 in 1992. It was renamed the Bureau of Postharvest Research and Extension (BPRE).

For years now, PHilMech is engaged in both postharvest research, development and extension activities. It has so far developed, extended and commercialized its research and development outputs to various stakeholders in the industry.

With Republic Act 8435 or Agriculture and Fishery Modernization Act (AFMA) of 1997, PHilMech takes the lead in providing more postharvest interventions to empower the agriculture, fishery and livestock sectors.

Pursuant to Executive Order 366 or the government's rationalization program in November 2009, BPRE became the Philippine Center for Postharvest Development and Mechanization (PHilMech) with twin mandates of postharvest development and mechanization.

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