IJPSR (2025), Volume 16, Issue 5 **(Research Article)**

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 07 December 2024; received in revised form, 30 December 2024; accepted, 08 January 2025; published 01 May 2025

COMPARATIVE ANALYSIS OF NUTRITIONAL PROPERTIES, SYNTHESIS OF PECTIN, RESINS AND GREEN SURFACTANT FROM THREE VARIETIES OF *MORINGA OLEIFERA* LEAVES

Sindhu Anoop * and Monalisha Tantubai

Department of Biotechnology, Mount Carmel College Autonomous, Palace Road, Vasanth Nagar, Bangalore - 560052, Karnataka, India.

Keywords:

Moringa oleifera, Resins, Biosurfactant, Nanoparticles, Protease, Pectin

Correspondence to Author:
Dr. Sindhu Anoop

Associate Professor,
Department of Biotechnology, Mount Carmel College Autonomous, Palace Road, Vasanth Nagar, Bangalore - 560052, Karnataka, India.

E-mail: sindhuanoop0@gmail.com

ABSTRACT: In the present era, plant derived green products are gaining a lot of importance due to their ecofriendly nature, unique chemical compositions and mode of action. In the present study, three varieties of *Moringa oleifera*, *namely* Shyama- black color variety (most found), Shveta - white color variety and Rakta - red color variety (less found) were used for the synthesis of biosurfactant, pectins and resins. The results of the study indicated that the varieties were good sources of pectin, showing that the samples could be efficiently used in many food processing industries as a gel forming, thickening agent and as a stabilizer. Natural resins were synthesized from the varieties of *Moringa oleifera* leaves. The results obtained from the present study showed that *Moringa oleifera* could be a potential source of plant derived resins with application in medicine and pharmacy as many plant resins have been observed to elicit pharmacological effects. Biosurfactants were obtained from the leaves of the plant samples thus proving to be suitable for the formulation of green products that require reduction of surface tension and formation of emulsions. The present work is focused on utilizing plant derived bio sources with potent applications in the rubber, detergent, food and cosmetic industry, therefore making sustainability the theme of modern research and development.

INTRODUCTION: Products obtained from plants are used to treat various diseases compared to the use of synthetic drugs which have side effects. Hence, the field of traditional medicine showed a drastic amount of growth in the last few years. The goals of food biotechnology today have changed, and focus on more abundant, affordable and more nutritious supply of food to fulfil the needs of the growing population day by day.

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.16(5).1409-18

This article can be accessed online on www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.16(5).1409-18

In the food industry, products obtained from plant extracts are used to improve the safety, nutritional value and shelf life of food products. The phytocompounds possessing antimicrobial activity have been used in food packaging materials to ensure inhibition of microbial growth and therefore prolong the freshness of perishable food items [2].

Pectins belong to a family of complex polysaccharides present within the primary cell wall and intercellular regions of dicotyledons and provide flexibility and mechanical strength to plants. In the past many companies began producing pectin because of the large quantities of fruit left over from the juice and wine industries, especially apple or citrus pulps. Pectins are used in the pharmaceutical, food and cosmetics industries

to stabilize acidified milk drinks or juice and as a gelling or thickening agent in jams and jellies [4]. Commercial pectins have been extracted from peels of citrus fruits including lemon, lime, orange (85.5%), apple pomace (14.0%), and sugar beet pulp (0.5%) by acid extraction at pH 1.5–3.0 with conventional heating techniques (60–100°C) for several hours. However, pectin yield and the physicochemical characteristics of recovered pectin depend on the extraction methods, extraction time, pH, acid used for extraction, temperature and liquid solid ratios [3]. Apple pomace and citrus peels are available in large amounts as byproducts of the fruit juice and essential oil industry, whereas sugar beet pulp is obtained from the sugar industry. While citrus peel contains 20–30% pectin on a dry matter basis, apple pomace contains 10–15%. Recently, more research has been carried out to extract pectin from alternative sources [5].

Watermelon, a tropical/subtropical fruit, also has been found to have high pectin content (13–30%) and the recorded yield of pectin was 28%. Pectin has been extracted from both dry and green pods of *Moringa oleifera* [40]. The dry and wet moringa pods were characterized, and humidity values of 12.12 and 23.18%; ash 1.75 and 0.67%; proteins 20.62 and 5.91%; pH 6.15 and 6.86, density 0.91 and 0.18 g/mL were obtained respectively. For pectin extraction, the acid hydrolysis method was used and was found to be 41% for the green pods at pH 2 and 30% for the dried ones at pH 3 at 90°C and 90 minutes. The pectin with higher yield was characterized physiochemically and yield of 3.45% with 1.3% of ash, gelling time of 4 minutes, 15% in degree of esterification and 73.92% of galacturonic acid was obtained [7].

A sensory analysis was carried out of the jam made with the pectin and the results obtained was rated as excellent. Therefore, it is concluded that the pectin obtained is of low methoxy, slow gelation and high purity and it can be used to make jam, with good sensory acceptance [39]. Pectin is an important polysaccharide in food because of its functional property. It has the ability to form gels in an acidic medium and in the presence of sugars. For this reason, it is used in the food industry as a thickening agent [6]. Surfactants of plant origin are widely distributed in nature and can be classified as phospholipids, proteins or protein hydrolysates and saponins. Among these, saponins are widely distributed in the plant kingdom and are characterized by their structure containing a steroidal or triterpenoid aglycone linked to one or more sugar molecules. Saponins or saponin-rich extracts have the potential for several biotechnological applications due to their physical-chemical and biological properties. In addition, saponins have shown great potential for application in cosmetics such as shampoos, conditioners and skincare products [8]. In this present era there is growing demand for green cosmetics and the importance of surfactants to accompany this trend, the present study was focused to optimize the extraction process of biosurfactants from leaves of three varieties of *Moringa oleifera* and to characterize the plant extracts in terms of their surfactant and emulsifying properties, with a goal to facilitate the future application of these agents in the cosmetic industry [10].

Plant derived resins are secondary metabolites of complex mixtures, that include volatile and nonvolatile terpenoid and/or phenolic compounds. They often exist in combination with essential oils (oleoresins), gums (gum resins), oil and gum (oleo-gum resins) sugars (as glycosides), and benzoic/cinnamic acid (balsams). Phenolic and terpenoid resins have been identified with the former consisting majorly of the internally formed resins while the latter largely constitute resins formed on the surface. Many plants derived resins have been observed to elicit pharmacological effects and find applications in medicine and pharmacy [9].

Biophenol-furfural resin has been successfully synthesized from monosaccharides and their derivatives prepared from naturally occurring *Moringa oleifera* gum. Different resins synthesized by varying the biophenol to monosaccharide ratio exhibited the glass transition temperature in the range of 16 °C to 31 °C. Characterization of the resin was done by FTIR, 1H NMR, TGA and DSC. The molecular weight of the resins was in the range of 652 m/z to 1291 m/z [11]. In the current industrial market, the most important resin is phenol formaldehyde resin. In view of the rising petroleum prices and environmental concerns, most of the industrial research has been focused on finding the replacement of phenol with some biophenols.

In this work resin was synthesized from the leaf varieties of *Moringa oleifera* by acid-catalyzed mixture condensation reactions with the aim of it serving as a potential source of resin with applications in the adhesive and binder industry [12].

MATERIALS AND METHODS:

Collection of Samples: The leaf samples of three varieties: Shyama- black color variety, Shveta - white color variety and. Rakta - red color variety of *Moringa oleifera* plant were obtained from the local market of Vasanth Nagar, Bangalore, Karnataka (the following and were authenticated at the Department of Botany, Mount Carmel College. It was dried in air for two to three weeks and ground into a powder with a mixer, passed through a tea strainer to obtain the powdered sample. The sample powder recovered was stored in clean bottles at 97℃ until used for further studies.

Preparation of Plant Extract: Two grams of powdered samples of each of the three varieties were dissolved in 40ml of distilled water. The mixture was then mixed thoroughly for a longer period of time using a magnetic stirrer and then it was kept aside for 48 hours. It was stirred again using a magnetic stirrer at faster speed for 30 minutes and filtered using high grade filter paper and was stored in a flask. The resultant filtrate was then kept for evaporating at room temperature using a water bath to get the crude form of the sample used. Again, the same method was sused, in the case of all the three samples respectively. The extract obtained was stored in a chiller at a temperature of 4℃ for further use.

Evaluation of the Potency of the Sample for the Production Of Cost Effective Biosurfactant Organism and Culture Conditions: Pure cultures of microorganisms were obtained, and Gram staining was performed for identification. The organisms after identification were sub-cultured in nutrient agar plates and stored in nutrient agar slants at 4℃ until needed for use.

Preparation of Inoculum and Media: The inoculum was prepared in nutrient broth medium and was incubated at 30℃ for a day. The minimal medium was prepared. Carbon sources were added separately in the autoclaved medium for further use. Aqueous extract of the leaves was used as a carbon source. The extract obtained was filtered through Whatmann filter paper no. 1 and clear filtrates were re- autoclaved [14].

Biosurfactant Extraction and Purification: To produce biosurfactant, in media prepared as described above, the cultures were grown at 30°C for 24 hours. The crude form of biosurfactant was obtained by centrifuging the culture containing leaf extract as carbon source at 12,000 rpm for 30 minutes at 4°C. The supernatant was collected and was acidified with 6 N HCl and kept for precipitation at 4°C 24-48 hours. The precipitate was collected by centrifugation at 12,000 rpm for 30 minutes at 4°C and was then suspended in minimum volume of distilled water, neutralized with 1 N NaOH and kept on magnetic stirrer for 1 hour to dissolve it completely. The aqueous solution was collected and is mixed with equal volume of chloroform: methanol (2:1) and organic phase was collected. For maximum biosurfactant recovery the whole procedure is repeated at least thrice [1].

Emulsification Stability Test: Two ml of diesel and two ml of supernatant solution were vortexed for about 2 minutes. The height of the different layers formed was checked. Tubes were incubated for 24 hours under a normal standard temperature. The height of the emulsified layer and the total height of the liquid was measured. The emulsification index was calculated using a standard formula by dividing the height of the emulsified layer (mm) with the total height of the liquid (mm) and multiplied by 100. The sample that showed the maximum height of the emulsified layer indicated more foam activity with high detergent property [15].

Green Synthesis of Silver Nanoparticles from the Plant Sample: The leaf samples were collected and were air dried for ten days and then kept in the hot air oven at 60℃ for 24 to 48 hours. The leaves were ground to a fine powder.

Solvent Extraction: Ten grams of air-dried powder was placed in 100 ml of organic solvent (90% methanol) in a conical flask, plugged with cotton and then kept on a rotary shaker at 180 to 200 rpm for 24 hours. After 24 hours, it was filtered through 4 layers of muslin cloth and

centrifuged at 5000 rpm for 10 minutes. The supernatant was collected, and the solvent was evaporated. The crude extract diluted with 5% of DMSO to make the final volume one-tenth of the original volume and stored at 4℃ in airtight bottles for further studies [19].

Synthesis Step of Silver/Leaf Emulsion: The extracts of the plant sample were taken and added to the ionized water and mixed very well for about four hours. Forty ml of silver nitrate was added and was slowly mixed at 25℃ for a day. The silver nanoparticles were obtained slowly during the period of incubation. During the process, the mixed solution was kept at an exact moderate temperature in a dark surrounding [13]. At last, the mixture of silver nanoparticles and the leaf samples were centrifuged and washed about four to five times to remove any kind of silver ions. The nanoparticles precipitate obtained was kept at 30℃ and was dried to get the last product which is silver nanoparticles. The tubes were vortexed and were covered with aluminum foil to avoid the evaporation of the sample and incubated in water bath at 98℃ for an hour. The tubes after incubation were cooled under room temperature and were estimated spectrophotometrically at 520 nm [34].

Extraction of Protease and Immobilization of the Enzyme: The samples were homogenized using mortar and pestle with phosphate buffer pH 7.0 and was centrifuged at 10,000 rpm for 10 minutes. The supernatant was collected and was subjected to further purification [16].

Partial Purification of Enzyme: The protein from the crude enzyme was precipitated using 70% ammonium sulphate. Then it was fed into sephadex column for desalting [26].

Estimation of Protein Concentration: The protein concentration of the samples was estimated by Bradford method [17].

Immobilzed Protease Activity: The partially purified enzyme solution (0.5 ml) was mixed with 1ml of sodium alginate. The mixture was pipetted out into calcium chloride using sterile syringe. Beads were formed and were counted. These beads containing enzyme were mixed with 0.5ml casein and 10% TCA was added to it. Then it was centrifuged, and the supernatant was taken. The supernatant was mixed with protease reagent and Folins phenol reagent and was spectrophotometrically estimated at 650nm. The activity was checked every 5 minutes to find out the time for maximum activity [21].

Estimation of pH: The optimum pH of the protease was assayed using phosphate buffer at pH 5.7, 6.2, 6.7 and 7.2 [28].

Extraction and Evaluation of Pectin Content: *Moringa oleifera* leaves of three varieties were used as a main source for pectin extraction. The leaves were then dried at 60℃ for a whole day, and ground using a mixer and passed through a strainer [18].

Alcohol Insoluble Solids Preparation (AIS): Dried powder of the samples was collected and homogenized using boiled ethanol in mortar and pestle with a final ethanol concentration of 80% to inactivate various kinds of endogenous enzymes and other solids that are soluble in alcohol. The mixture was washed with ethanol over 3-4 times and was stored at 40℃ for 24 hours to remove any kind of moisture and was again weighed [27].

Pectin Extraction: Five to ten grams of AIS was heated with 100 ml of extraction solutions. After extraction, the mixture was brought to room temperature and was cooled. It was then centrifuged at 8000rpm for 10-15 minutes. The supernatant obtained was filtered through filter paper to remove any trace of impurity.

The filtrate obtained was mixed with volume equal to that of 95% ethanol which contained 0.05M of HCL. The mixture was then washed with 95% ethanol and kept at 40℃ in a hot air oven till the time it fully dried [27]. Pectin Yield was calculated using the formula:

Pectin yield (%) = Amount of pectin extracted (g) x 100 / Dry weight of *M. oleifera* extract (g)

Determination of the Moisture Content: One gram of the sample of pectin was taken and weighed; it was then ground and passed through screen and was kept in a dish. Then the sample was dried using a oven for about five hours at 100℃, followed by cooling it and was again weighed.

The sample was then not further used for the study as pectin can degrade when it comes in contact with the environment [29].

Moisture content (%) = (weight of residue x 100) /Weight of sample

Determination of Ash Content in the Sample: One to two grams of the pectin sample was taken and was ground and passed through mesh screen, it was then heated at a very high temperature for about three to four hours. After that the alkaline nature of the ash obtained was checked using zero-point one normal hydrochloric acid and was allowed to boil and was finally cooled. The solution was then titrated with the sodium hydroxide along with using phenolphthalein indicator [28]. The ash content of the sample was calculated using the formula:

Ash content (%) = (weight of ash x 100) / weight of pectin (g)

Determination of Equivalent Weight of the Sample: The equivalent weight is a parameter that is used to calculate the was used for calculating the anhydrouronic acid concentration and the degree of esterification. It was done by performing titration with sodium hydroxide to a specific pH of seven point five making use of phenol red as an indicator. The equivalent weight of the sample was calculated using the equation [20]:

Equivalent weight (EW) = (weight of sample (g) x 1000) /Volume of alkali (mL) x Normality of alkali (N)

Synthesis And Production of Resins Using the Leaf Sample Collection of the Plant Material: The leaf samples were collected and were dried for about ten days and then kept in the hot air oven at a very high temperature for about one to two days. The samples were then ground to powdered form.

Conversion of Soluble Polysaccharide to Monosaccharide: Dried and grounded powdered sample was boiled in pure water at a high temperature for different intervals. But the soluble part containing the polysaccharide was allowed to separate using glass fiber filters. Solid form of the result was taken and evaporated followed by precipitation of the saccharide by adding cool ethanol in the ration of 3:1, thereby as ethanol: filtrate. The maximum amount of polysaccharide was obtained by boiling the sample at 100 ℃ for about one hour. Hence, after this step the conditions are kind of fixed for the separation of the saccharide from the sample. The polysaccharide was converted to monosaccharide by performing hydrolysis of acid using 5N Sulphuric acid at 100℃ temperature [35].

Resin Synthesis from the Sample: By emphasizing the weight of the saccharide obtained, phenol was accordingly poured in a flask and was subjected to vigorous stirring. Acid-catalyzed mixture condensation reactions of the bio phenol and monosaccharide was done by using different catalysts. Temperature, reactant ratio, time and were also changed accordingly to obtain optimum reaction conditions. Finally, four resins with a ratio of different reactants used were synthesized at 130℃, for seven to eight hours time, making use of Sulphuric acid as the catalyzing agent. The mixture was then again mixed at a low speed and the resin obtained was further purified using the evaporation step. At last, the mixture was diluted by using acetone and the final precipitation of the resultant resin happens in the mixture of water and methanol [35].

Measurement of Acidity Profile of the Leaf Sample: The acidity of the samples was determined. Five ml of the sample was dissolved in 50ml double distilled water and from the total amount; about 20ml of aliquot was taken in a 100ml flask and was titrated with 1N sodium hydroxide using few drops of phenolphthalein solution (indicator). The reading at the end was determined by observing the pink color. The titration done was used to note down the values and was used to calculate total acids present using the equation [38]:

Acidity (%) = Vol. of NaOH used (ml) X Normality of NaOH X Equivalent Wt. of tartaric acid / Vol. of sample (ml) titrated × 100

RESULTS AND DISCUSSION:

Evaluation of Potency of the Sample in Production of Cost Effective Biosurfactant: Now a days, cheap raw materials are being used for the growth and production of biosurfactants, thereby making the production cost of biosurfactants less than other methods [22]. When various domestic kitchen wastes and extracts in aqueous form of agriculture based industrial wastes like *Moringa*

oleifera leaves, peels of different fruits added in the final media, it acts as a carbon source to produce novel biosurfactants. By repeating the protocol for a greater number of times, maximum production of biosurfactant was observed as shown in **Fig. 1.**

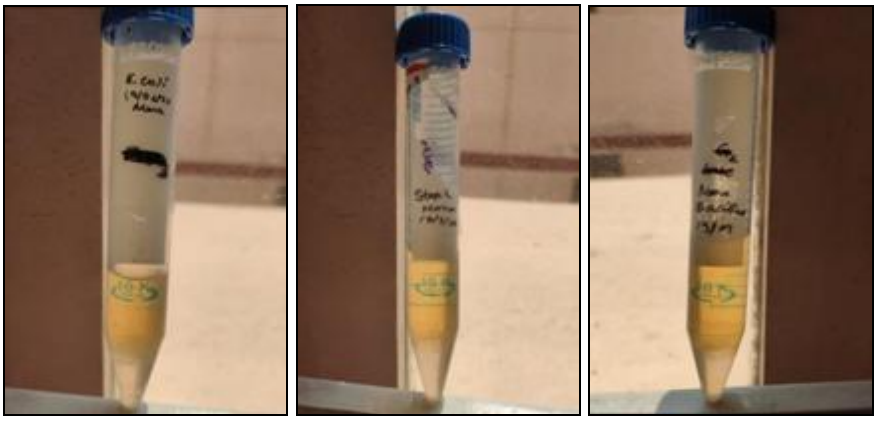

FIG. 1: LAYER OF BIOSURFACTANT FORMED

Tests to check the oil degrading capacity of plant derived biosurfactants were carried out to identify the variety which has emulsifying capacity [23]. The emulsification index showed that out of the three varieties, the black variety showed more ability of degrading oil which as mentioned in **Table 1.** The foaming capacity is analyzed by emulsification stability test method where in it is estimated as a value of percentage of the foam layer formed from the total sample after incubation time [24].

TABLE 1: EMULSIFICATION STABILITY TEST OF THREE PLANT EXTRACTS

Plant varieties	Sample height (mm)	Foam layer (mm)	Aqueous layer (mm)	Total height (mm)	Emulsification index (%)
Shyama	2	0.4	1.1	3.5	11.4285
Shveta	1.8	0.3	1.3	3.4	8.82352
Rakta	2.6	0.3	1.1	4	7.5

Synthesis and Production of Silver Nanoparticles Using the Leaf Samples: The reaction works as reduction of silver ions into silver nanoparticles when it is exposed to *Moringa oleifera* leaf sample and then color change is also observed. The new mixture/ suspension of *Moringa oleifera* leaf sample was found to be partially green in color. But, just after adding silver nitrate and performing mixing step for one day at 97℃, for one full day at room temperature, the emulsion changed to brown in color [25]. Due to presence of SPR, surface plasmon resonance phenomena color changes happened in the results. *Moringa oleifera* leaf can act as an aldehyde and can cause reduction of silver ions to silver nanopaticles.

UV-Visible Spectroscopy Analysis: Production of Ag-NPs were continued by taking count of the SPR of the *Moringa oleifera* leaf sample and subsequently silver/sample mixture at a wavelength range of three to eight hundred nm. In the display, the bands of SPR obtained are controlled/affected by its morphological parameters [30]. Absorption peak that was created slowly started shifting from 425-450nm [31] and the changes were also observed in peak intensity and with the shape of the spectra formed. Through the relevant changes obtained, there is one thing clear that for testing of emulsion stability, first the stability level of Ag and Sample mixture becomes less and then slowly the dimensions of the silver nanoparticle increases.

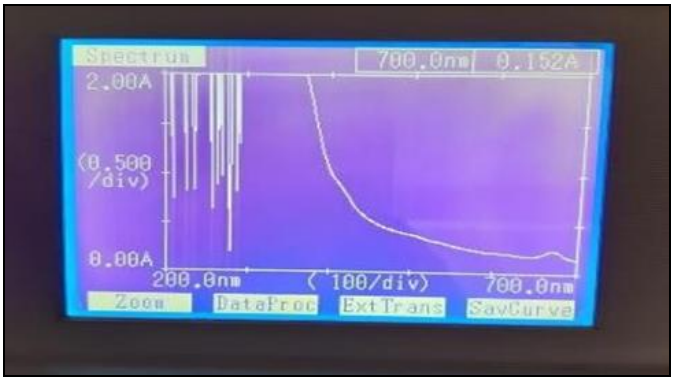

FIG. 2: UV-VISIBLE SPECTROSCOPY ANALYSIS OF LEAF EXTRACT SAMPLES

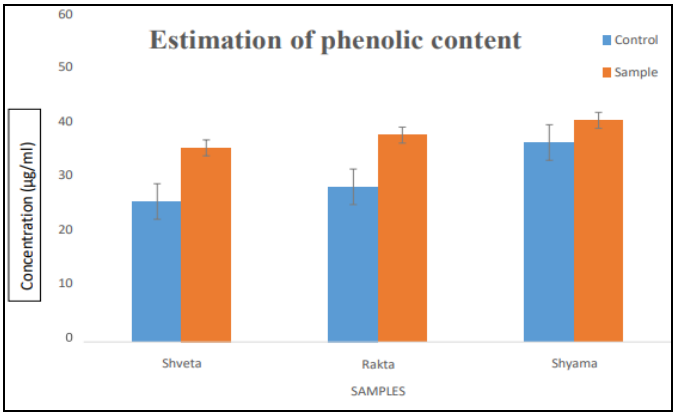

FIG. 3: ESTIMATION OF PHENOLIC CONTENT OF THREE LEAF VARIETIES OF *MORINGA OLEIFERA*

Among the three species of leaf sample, Sample 1, Shveta showed the lowest phenol content of 52.54±10.93µg/ml, compared to Sample 2, Rakta 56.00±4.06µg/ml and Sample 3, Shyama 60.00±02.01µg/ml. Shyama, the black variety showed the highest phenol content of 60.00±02.01µg/ml. Phenolic compounds are important phytoconstituents with redox properties, thus imparting antioxidant activity since hydroxyl groups in these compounds and are responsible for the free radical scavenging activity [32]. They have a major role in determining the antioxidant capacity of many plants.

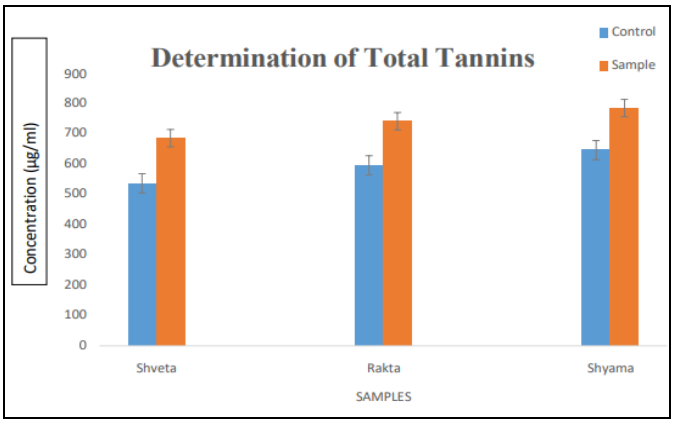

FIG. 4: ESTIMATION OF CONDENSED TANNINS IN THREE LEAF VARIETIES OF *MORINGA OLEIFERA*

Total tannin content in Sample 1, Shveta is found to be 690.00±155.88µg/ml, the second variety of *Moringa oleifera* leaves (Sample 2), Rakta showed tannin content of 746.35±56.37µg/ml and the third sample (Sample 3), Shyama showed tannin content of 790.00±10.00µg/ml. Immobilizing enzyme is a phenomenon used to block the enzymes from leaving while the substrate and the leftover products pass through [33]. In the study conducted, protease enzyme was separated from the three varieties from leaves of *Moringa oleifera* and was partially purified. After the partial purification step, concentration of the protein was checked. The protease obtained was then immobilized very carefully on sodium alginate matrix. The matrix used should be non-degradable in nature and compatible with the enzymes and process should be mild [36].

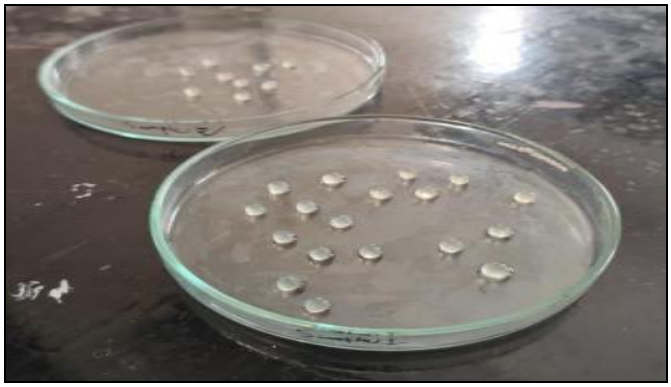

FIG. 5: IMMOBILIZED PROTEASE ENZYME

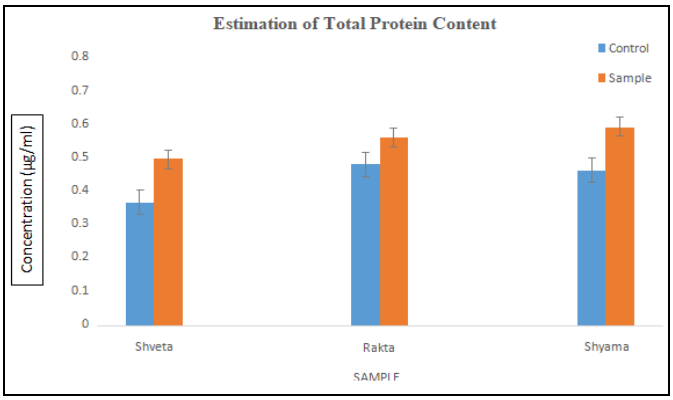

FIG. 6: DETERMINATION OF TOTAL PROTEIN CONTENT

Among three varieties of leaves (samples) used, Sample 1, Shveta showed the lowest protein content of 0.62±0.08µg/ml, compared to Sample 2, Rakta 0.7±0.04µg/ml and Sample 3, Shyama 0.74±0.06µg/ml. The black variety showed the highest protein content of 0.74±0.06µg /ml.

pH Estimation: The optimal amount of pH was checked out for all the samples that were immobilized at four completely different pH and even the free sample was measured. For the free sample, it turned out to be 5.50 and for Beads it was found to be 7.59. The results depict a method for preparing plant derived immobilized protease such that the biocatalyst is protected in the inner biocompatible alginate core and its pH was optimized.

In future other parameters of immobilized protease can also be investigated for cost effective production [37]. In this study, the leaves from two different varieties of *Moringa oleifera* were taken for pectin extraction and further evaluation. Shveta and Shyama are the most produced variety, the two leaf varieties were selected based on more amount of utilization in the country. The two varieties belonged to the same genomic group Moringa.

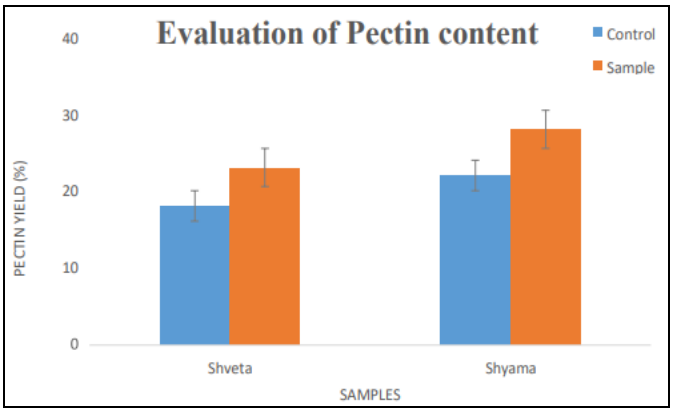

FIG. 7: EVALUATION OF PECTIN CONTENT IN THE LEAF SAMPLES OF TWO VARIETIES

It was observed that the (Sample A) White Variety "Shveta" produced the lower yield of pectin of 40.84% compared to (Sample B) Black Variety "Shyama" which showed pectin recovery of 49.6%. The leaves of Black and white varieties of *Moringa oleifera* were used to determine the moisture content. White and black variety showed moisture content of 38.08% and 40.62% respectively. The content of moisture present in the pectin sample showed variation with the other variety of the same plant itself. Less amount of moisture is important for pectin for storage methods and doesn't allow the growth of various kinds of microbial cells. This growth of microbes could have affected the quality of enzyme present.

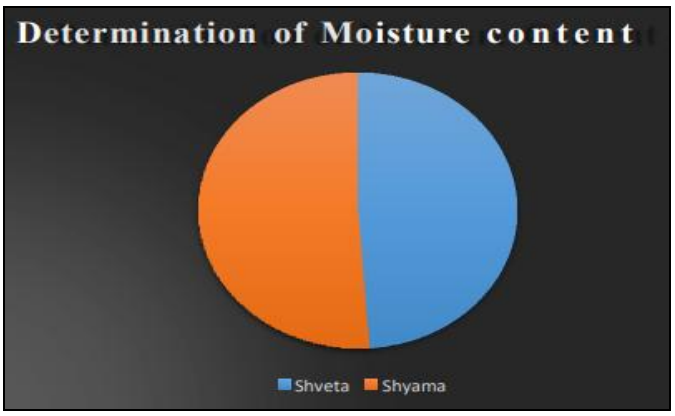

FIG. 8: DETERMINATION OF MOISTURE CONTENT

White and black variety showed ash content of 39.78% and 45.13% respectively. Shyama (Black Variety) showed the highest amount of moisture compared to Shveta (White variety). Pectin is a not fully esterified poly galacturonase compound, it bears only 10% or more materials that are organic in nature and are mixture of many other kinds of sugar molecules. AUA (%) is an important factor to obtain the purity level of the enzyme extracted from the sample and emphasizes the physical characteristics of the same. The solubilizing levels of the leaf sample were checked by using different solvents. At 97°C, *Moringa oleifera* leaf samples were found to be not soluble in all types of solvents that are commonly used. But the sample was found to be partially soluble in hot water. Natural resins possess an amorphous part in it. The rest of the part is crosslinked bio fibers and closelylinked as carbohydrates by means of hydrogen bonding. At a temperature more than 70°C, it has been observed that the crosslink part had increased in diameter in water and there by the remaining part that is, the amorphous one could be very easily separated and dissolved in water more than 70°C. The solubility profile of the sample was found approximately to be 26.78% (w/w)

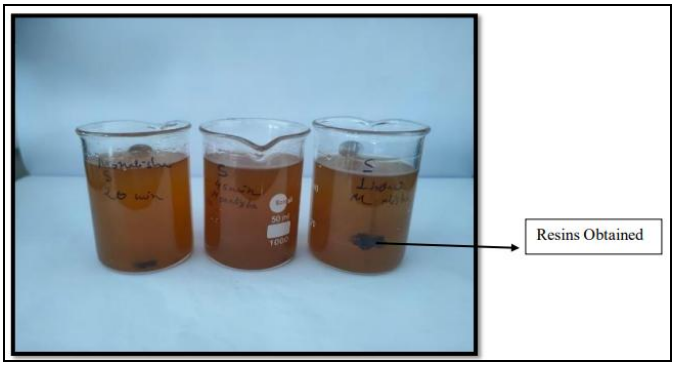

FIG. 9: PRODUCTION OF PHENOL FURFURAL RESIN

The yield of the black variety resin was calculated to be 12.17 g. The resin was freely soluble in organic solvents but almost insoluble in water. Pharmaceutical excipients derived from natural sources like resins are nowadays meritoriously used in the formulation of drugs. Resins of natural origin have many advantages over chemically synthesized substances; they are safer, nontoxic, less expensive, biodegradable, and widely available.

CONCLUSION: From the study conducted using the leaves of three varieties of *Moringa oleifera*, it

was found that the sample had huge number of industrial applications. The results suggested that there are not only many varieties of plants being used as a medicinal purpose, but also different parts of the plants have great potential to combat diseases. It also gives insights to conservation of easily detachable plant parts such as leaves rather than wastage of it. Further research needs to be done into the identification and isolation of leaves from many other varieties of plants around the globe which could be exploited for further pharmaceutical use. The findings of the present study also show that the leaves of the plant sample used can be used as an effective carbon source to produce biosurfactants. Biosurfactants are compounds which are amphiphilic Resins Obtained in nature, are produced on the surfaces, generally on the layers of cells containing microbes or can be excreted as solvent loving and solvent hating groups. Pectin has also been extracted from the two varieties of samples used which throws more light on the fact that the samples can be efficiently used in many food processing industries as gelforming, thickening agent and as a stabilizer.

It can also be used as thickening agent in jams and increases the gel strength of low calorific value jams. Different types of phytochemical components have also been found in the samples used which gives a strong point in using the leaves for medicinal purposes. Further research needs to be done towards the identification and isolation of leaf samples from many other varieties of plants around the globe which could be exploited for further pharmaceutical use. Studies were done to check if the sample material can form novel silver nanoparticles. But in future, more studies related to plants and its medicinal properties and its relation to production of nano materials are hopefully coming as broad spectrum.

The synthesis of a completely bio-based resin from the natural *Moringa oleifera* leaves was presented in this study. The results of the present work established a bio resin synthesis method and its applicability as a process aid in the rubber industry.

ACKNOWLEDGMENTS: We would like to express our sincere thanks to the Management and Principal of Mount Carmel College for supporting us in carrying out this work.

CONFLICTS OF INTEREST: None

REFERENCES:

1. Selvakumar P: Phytochemical and Pharmacological Profile Review of *Bryophyllum pinnatum*. Biomedical and Biotechnology Research Journal 2022; 6(3): 295-301.
2. Kafuku G and Mbarawa M: Alkaline catalyzed biodiesel production from *Moringa oleifera* oil with optimized production parameters. Appl Energy 2010; 87(8): 2561-5.
3. Ogidigo, JO, Anosike CA, Joshua PE, Ibeji CU, Nwanguma BC and Nwodo OFC: Neuroprotective effect of *Bryophyllum pinnatum* flavonoids against aluminum chloride-induced neurotoxicity in rats. Toxicology Mechanisms and Methods 2022; 32(4): 243-258.
4. Abbas RK and Elsharbasy FS: Antibacterial activity of *Moringa oleifera* against pathogenic bacteria in Sudan. Int J Curr Res 2019; 11(1): 27-30.
5. Karnwal, A, Shrivastava S, Al-Tawaha ARM, KumarG Singh and Kumar RA: Microbial biosurfactant as an alternate to chemical surfactants for application in cosmetics Industries in Personal and Skin Care Products: a critical review. Biomed Res Int 2023; 12(1): 1–21.
6. Ganie SA, Zaffer M, Gulia SS, Yadav SS, Singh R and Ganguly S: Antifungal efficacy of *Moringa oleifera* Lam. Am J Phytomedicine Clin Ther 2015; 3: 28-33.
7. Adu SA, Twigg MS, Naughton PJ, Marchant R and Banat IM: Characterisation of cytotoxicity and immune-modulatory effects of glycolipid biosurfactants on human keratinocytes. Applied Microbiology and Biotechnology 2023; 107: 137–152.
8. Sahabjada, Ahmad MS, Ahmad S, Jafri A, Khatoon A, Kashyap A and Arshad M: Antioxidant, osteogenic, antimicrobial and nutritional potential of *Moringa oleifera* Funct Biol Biotechnol 2014; 1: 10-16.
9. Nazmy SE, Hassan BH, Alnidawi NAA, Elhalwagi AE, Abd Elhamid EM and Farid M: Biochemical studies on Moringa oleifera leaves extract. J Biol Agric Healthcare 2016; 6(16): 58-64.
10. Ragasa CY, Medecilo MP and Shen CC: Chemical constituents of *Moringa oleifera* Lam. leaves. Der Pharm Chem 2015; 7(7): 395-399.
11. Ismail SA and Ganzour SK: Efficiency of foliar spraying with moringa leaves extract and potassium nitrate on yield and quality of strawberry in sandy soil. Int J Agric Stat Sci 2021; 17: 383–398.
12. Mamgain A, Kenwat R and Paliwal R: Phytochemical Profiling and Molecular Investigation of *Moringa oleifera* Lam. leaves for anti-arthritic potential: assessment and identification of phytopharmaceuticals through GC-MS analysis, *in-silico* study, ADMET Analysis, and *in-vitro* Evaluation. Current Biotechnology 2024; 13(3): 140-58.
13. Mehmood A, Naveed K, Ayub Q, Alamri S, Siddiqui M.H, Wu C, Wang D, Saud S, Banout J and Danish S: Exploring the potential of moringa leaf extract as bio stimulant for improving yield and quality of black cumin oil. Sci Rep 2021; 11: 24217.
14. Mamgain A, Kenwat R and Paliwal R: Phytochemical profiling and molecular investigation of *Moringa oleifera* lam. leaves for anti-arthritic potential: assessment and identification of phytopharmaceuticals through GC-MS analysis, *in-silico* study, admet analysis, and *in-vitro* evaluation. Current Biotechnology 2024; 13(3): 140-58.
15. Na-Allah Y, Bello A and Kabir N: Evaluation of nutrient and anti-nutritional factors of leaves of Moringa (*Moringa oleifera*) in Sokoto, Nigeria. Direct Res J Agric Food Sci 2017; 5(12): 433-437.

16. Kafi S and Elbir H: The antimicrobial activity and phytochemical characteristics of *Moringa oleifera* seeds, leaves, and flowers. World J Pharm Res 2014; 4(1): 258-271.
17. Tholl D: Biosynthesis and Biological Functions of Terpenoids in Plants. In Biotechnology of Isoprenoids. Advances in Biochemical Engineering/Biotechnology; Schrader, J., Bohlmann, J., Eds.; Springer: Cham, Switzerland 2015; 63–106.
18. Palafox J, Navarrete A, Sacramento-Rivero J, Rubio-Atoche C, Escoffie P and Rocha-Uribe J: Extraction and characterization of oil from *Moringa oleifera* using supercritical CO2 and traditional solvents. Am J Anal Chem 2012; 3: 946-949.
19. Banik S, Biswas S and Karmakar S: Extraction, purification and activity of protease from the leaves of *M. oleifera.* F1000Res 2018; 7: 1151.
20. Rolim LADMM, Macedo MFS, Sisenando HA, Napoleao TH, Felzenszwalb I, Aiub CAF, Coelho LCB, Medeiros SRB and Paiva PMG: Genotoxicity evaluation of *Moringa oleifera* seed extract and lectin. JFS 2011; 76(2): 53-58.
21. Moodley JS, Naidu SB, Krishna S, Pillay K, Sershen and Govender P: Green synthesis of silver nanoparticles from *Moringa oleifera* leaf extracts and its antimicrobial potential. Adv Nat Sci Nanoscience Nanotechnol 2018; 9(1): 015011.
22. Yap YK, El-Sherif F, Habib ES and Khattab S: *Moringa oleifera* leaf extract enhanced growth, yield, and silybin content while mitigating salt-induced adverse effects on the growth of *Silybum marianum*. Agronomy 2021; 11: 2500.
23. Sharmila S, Jeyanthi Rebecca L and Saduzzaman M: Immobilization of plant protease using calcium alginate beads. J Chem Pharm Res 2012; 4(10): 4484-4488.
24. Khalid S, Arshad M, Mahmood S, Ahmed W, Siddique F, Khalid W and Hassan FAM: Nutritional and phytochemical screening of *Moringa oleifera* leaf powder in aqueous and ethanol extract. International Journal of Food Properties 2023; 26(1): 2338–2348.
25. Muhammad AA, Pauzi NA, Arulselvan P, Abas F and Fakurazi S: *In-vitro* wound healing potential and identification of bioactive compounds from *Moringa oleifera* Lam. Biomed Res Int 2013; 2013: 974580.
26. Singh Y and Prasad K: *Moringa oleifera* leaf as functional food powder: characterization and uses. Int J Agric Food Sci Technol 2013; 4: 23-30.
27. Jia L, Peng X, Deng Z, Zhang B and Li H: The structural characterization of polysaccharides from three cultivars of *Moringa oleifera* Lam. root and their effects on human intestinal microflora. Food Bioscience 2023; 52: 102482.
28. Nafi A, Ling FH, Bakar J and Ghazali HM: Partial characterization of an enzymatic extract from Bentong ginger. Molecules 2014; 19(6): 7392-405.
29. Quintero ME, Ramírez MCQ and Zafra LMC: Pectin extraction from the *Moringa oleifera* pods and its application in a jam. Res J Food Sci Nutr 2020; 5(5): 48-52.
30. Bunrathep S, Jongrungruengchok S, Vipunngeun N, Thongphasuk P and Songsak T: Pharmacognostic specification of *Moringa oleifera* Lam. leaves cultivated in Thailand. Rangsit J Arts Sci 2013; 3(1): 15-23.
31. Rahman IMM, Barua S, Nazimuddin M, Begum ZA, Rahman AM and Hasegawa H: Physicochemical properties of *Moringa oleifera* Lam. seed oil of the indigenous-cultivar of Bangladesh. J Food Lipids 2011; 16(4): 431-439.
32. Sudha R, Philip XC and Suriyakumari KVP: Phytochemical constituents of leaves of *Moringa oleifera* grown in Cuddalore District, Tamil Nadu, India. J Basic Clin Appl Health Sci 2020; 3(4): 164–167.
33. Rubio-Sanz L, Dorca-Fornell C, Fornos M, Navarro-Leon E and Jaizme-Vega MC: Phytochemical characterization of *Moringa oleifera* leaves. Int J Nat Fibers Med Plants Nat Res Inst 2021; 67(3): 1-8.
34. Fahal EM, Babitha Rani AM, Aklakur MD, Chanu TI, Saharan N: Qualitative and quantitative phytochemical analysis of *Moringa oleifera* (Lam) pods. Int J Curr Microbiol Appl Sci 2018; 7(5): 657-665.
35. Do BH, Hoang NS, Nguyen TPT, Ho NQC, Le TL & Doan CC: Phenolic Extraction of *Moringa oleifera* leaves induces caspase-dependent and caspase-independent apoptosis through the generation of reactive oxygen species and the activation of intrinsic mitochondrial pathway in human melanoma cells. Nutrition and Cancer 2020; 73(5): 869–888.
36. Calabrese EJ, Dhawan G, Kapoor R, Agathokleous E and Calabrese V: Moringa induces its beneficial effect *via* hormesis. Nutrition Res Reviews 2024; 37(2): 239-248.
37. Koley R, Rajkumar K, Sahoo S, Chattopadhyay S and Bhowmick AK: Synthesis and characterization of phenol furfural resin from *Moringa oleifera* gum and biophenol and its application in styrene butadiene rubber. Ind Eng Chem Res 2019; 58(40): 18519-18532.
38. Pravin D Badhe, Pranali D Bangaiya, Rutuja N Mule, Prashant Mali, Rutuja M Shinde, Swarda V Kamble, Leena Pathak and Ashwini P. Badhe: Evaluation of the toxicity, antioxidant, and antimitotic impact of *Moringa oleifera* using *in-vitro*, *ex-vivo*, and *in-vivo* models. Journal of Population Therapeutics and Clinical Pharmacology 2024; 31(2): 562-579.
39. Tiloke C, Phulukdaree A and Chuturgoon AA: The antiproliferative effect of *Moringa oleifera* crude aqueous leaf extract on cancerous human alveolar epithelial cells. BMC Complement Altern Med 2013; 13: 226.
40. Asare GA, Gyan B, Bugyei K, Adjei S, Mahama R, Addo P, Otu-Nyarko L, Wiredu EK and Nyarko A: Toxicity potentials of the nutraceutical *Moringa oleifera* at supra-supplementation levels. J Ethnopharmacol 2012; 139(1): 265-272.

How to cite this article:
Anoop S and Tantubai M: Comparative analysis of nutritional properties, synthesis of pectin, resins and green surfactant from three varieties of *Moringa oleifera* leaves. Int J Pharm Sci & Res 2025; 16(5): 1409-18. doi: 10.13040/IJPSR.0975-8232.16(5).1409-18.