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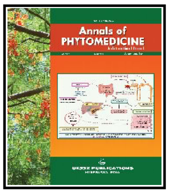

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Herbal excipients from agro waste: A review

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Abstract

Excipients are components used in pharmaceutical preparation which are necessary for drug distribution, preservation, stability, bioavailability, and product analysis. Natural excipients include agar, starch, alginate, carrageenan, xanthan gum, gelatin, acacia, pectin, tragacanth, guar gum and cellulose, which are utilized in the pharmaceutical industry as binders, retainers, preservatives, disintegrants, gelling agents, colloids, thickeners, suppository bases, stabilizers, and coatings. However, plant-based products confront a number of obstacles, including low energy usage, integrated processes, and intellectual property rights. The majority of pharmaceutical research focuses on natural polymers. Cellulose, the most popular natural substance, produces 50 billion tons of biomass annually. It is a linear polymer with a wide, rod-like shape that is determined by the length of the sugar chains. It has a wide range of uses, including food additives, papermaking, medicines, and chemical engineering. The disposal of agricultural and waste from industries is a severe concern in underdeveloped countries. Cellulose comes from vascular plants and is employed in several industries. The current article gives an overview on agro wastes as potential source for natural excipients.

1. Introduction

Excipients are defined as "materials used for preparation of medicines" (Morton's 1957). Specific applications of polysaccharide polymers in pharmaceutical formulations include aiding drug delivery during manufacturing, preservation, development or improvement of stability, bioavailability, or acceptability of the individual, assistance in product analysis, or other improvements in overall properties. Drug safety, efficacy, and management during preservation or usage. Some excipients of natural existence such as starch, agar, alginate, guar gum, carrageenan, gelatin, pectin, acacia, xanthan gum, tragacanth and cellulose are used in the pharmaceutical industry as binders, disintegrants, retainers, preservatives, colloids, thickeners and gelling agents, suppository bases, stabilizers and coatings (Wade *et al.*,1994).

There are sustainable ingredients as plants can be regenerated and grown or harvested sustainably. Food industry waste can be used as raw materials for the extraction of herbal excipients. These are another reason for the increasing demand for herbal products as excipients (Perepelkin, 2005). But, plant based products also present some challenges, such as low energy consumption and integrated processes, which can vary depending upon plants' locations and other factors, such as seasons. This can lead to long and costly separation and purification techniques. Intellectual property rights have also become an important concern (Lam 2007; Chesney *et al.,* 2007).

Plant based polymers have particular uses in medicinal product formulations, including the development of monolithic matrix systems, surgical implants, films, beads, microscopic particles, tiny particles, inhalable as well as intravenous systems, and viscous liquid dosage forms (Pandey *et al.,* 2004; Chamarthy *et al.,* 2008; Alonso-Sande *et al.,* 2008). Natural polymers are capable of producing various products according to their properties and molecular weight, becoming the focus of most pharmaceutical research (Banker *et al.*,1987; Bhardwaj *et al.,* 2000). Apart from extraction of herbal excipients cellulose from agro waste, this review also covers other natural excipients.

2. Pharmaceutical excipient

Pharmaceutical excipients are inert substances which are paired with therapeutic components to produce a drug. Components of inactive compounds are considered excipients. Excipients have an increasing impact on the behaviour, efficacy, effectiveness and significance of medicinal products. Variability in active compounds, excipients, and manufacturing processes is a significant factor in different products (Bi *et al.*,1996).

2.1 Classification of excipients

Excipients are often categorized based on their purpose and function within medicinal formulations:

- Diluents, binders
- Disintegrants, lubricant
- Brightening film pastes and coating agents
- Colorants, plasticizers
- Suspending agents, preservatives, antioxidants

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- Flavoring agents, sweeteners, taste enhancers
- Printing inks, dispersants chewing gum (Bi *et al.*, 1996).

2.2 Advantages of natural excipients

- Natural excipients are safe and environmentally friendly because they are all derived from natural sources.
- All these natural/vegetable excipients are chemically carbohydrates, so these excipients are non-toxic substances.
- Natural additives are cheaper than synthetic additives and cost less to manufacture Since herbal excipients are obtained from natural sources, they do not have any side effects or adverse effects on the human body.
- Natural excipients are easily obtained from various natural sources (Poona *et al.,* 2018).

2.3 Disadvantages of natural excipients

- There are many possibilities of microbial contamination during the production of natural excipients exposed to the external environment.
- Production of herbal excipients depends upon the environmental, regional and climatic conditions. Consequently, the number of different natural aids also depends on various factors that cannot be changed. Hence, there is a slow processing rate for the production of natural excipients.
- Natural excipients have a very slow rate of production.

2.4 Ideal properties of herbal excipients

- They can be used practically
- They should be non-poisonous and mild in nature
- They should be volatile in nature
- They should be easily available and cheap
- They should not have specific colour, smell and taste
- They should have good water and lipid solubility
- They should be pharmacologically inactive (Shinde and Bodas Yadav, 2019).

2.5 Cellulose

Cellulose is the most abundant natural product in the world and produces 50 billion tons of biomass every year (Carlin, 2008). Cellulose is a linear polymer unlike starch, branches appear and the molecule adopts a broad and a rod-like conformation, aided by the equatorial conformation of glue residues. Most of the strength of the cellulose depends upon the length of chain or degree of polymerization, of all the sugars that make up the polymer molecule. Plant cellulose is generally a mixture of hemicellulose, pectin, lignin, and other substances, while microbial cellulose is pure and has a high moisture content, and is long-chain. Disposal of agricultural and industrial waste is a major concern in developing countries. Cellulose is a polysaccharide polymer.

Cellulose is an adaptable compound because of its high content and distinct features. The primary commercial suppliers of cellulose are plants with vascular systems. In terms of current society's environmental preferences, lignocellulosic materials, particularly agricultural industry leftovers, play an essential role as extra construction materials. While the majority of substances are formed of wood pulp, fibers from textiles are frequently not removed from wood fibers. Food additives, papermaking, medicines, and other chemical engineering activities including chromatography, dyes, and explosives all employ substances that use cellulose and its derivatives (Sundarraj and Ranganathan, 2018).

2.6 Gums

The gums are pathogenic substances caused by damage to plants or unexpected events like drought that tear away the membranes of cells, resulting in extracellular development (gummosis). Mucilage is a typical metabolic product that forms within cells and is not harmful to plants. Gums easily disintegrate in water, while the mucilage develops slimy clumps. The mucilage are biological compounds (Qadry *et al.,* 2008).

2.7 Pectin

Pectin comprise sugar-free, straight macromolecules produced by the cells of plants walls (Sahasathian *et al.,* 2007). In the dietary supplement business, small capsules containing folic acid were created by combining bentonite and gelatin polymer compounds to enhance durability. The combination of bentonite and gelatin polymeric matrix improved the folic acid absorption and decreased leakage when compared with bentonite separately. Additionally, these capsules retained a greater amount of folic acid following freeze drying and preservation (Madziva *et al.,* 2005).

2.8 Alginates

Alginates are natural polysaccharides monomers produced by brown seaweed (Phaeophyceae). Various salts can be produced from alginic acid, one of the most common of which being sodium alginate. Alginates provide a wide range of applications in drug administration, involving liposomes, matrix-type gel beads, controlling intestinal transit duration, local usage and developing tissues (Tonnesen *et al.,* 2002).

3. Cellulose containing agro waste

3.1 Garlic skin

The cellulose microfibers (CMF) and nanocrystals of cellulose (CNC) were isolated from garlic (*Allium sativum*) (Amaryllidaceae) peel fibers *via* alkaline and acid hydrolysis. Crude fibers, CMF, and CNC of garlic peel were examined using Fourier transform infrared (FT-IR) spectrum, thermogravimetric analysis (TGA), XRD (X-ray diffraction), scanning electron microscopy (SEM), and by using transmission electron microscopy (TEM). Cellulose nanocrystals have a spherical shape and size of 58-96 nm (Jeevan Prasad Reddy and Jong-Whan Rhim, 2014).

3.2 Sugarcane bagasse

Cellulose was isolated using chemical treatment of sugarcane bagasse (Poaceae) using HNO_3, NaOH and bleach. Nanocrystals were also prepared by extraction of cellulose by H_2SO_4 hydrolysis, after cleaning with distilled water along with acetone. The Fourier transform infrared (FTIR) spectroscopy, TEM, and XRD were utilized for describing the surface morphology of the resulting material. Temperature was measured by TGA/DTG. FTIR showed that the hemicellulose and lignin peak disappeared. These results were verified by TGA, which showed removal of non-cellulosic material. An X-ray diffractometer showed that the acquisition of cellulose nanocrystals by the array resulted in an increase in crystallinity. Cellulose nanocrystals have a spherical form and a diameter of 38 nm, whereas chemically pure cellulose has a diameter of 76 nm (Suter K. Evans *et al.,* 2014).

3.3 Date palm waste

Phoenix dactylifera L. belongs to Arecaceae family and commonly called as date palm contains cellulose (MD Imad Uddin *et al*., 2020). Cellulose was isolated upon bleaching the date palm stem waste using acidified sodium chlorite ($NaClO_2$) and delignified with NaOH. The mineral hydrolysis by acid (62 per cent sulfuric acid) was carried out at 45°C for 45 min for the production of crystalline nanocellulose. Fourier transform infrared spectroscopy and chemical structure characterization confirmed the elimination of non-cellulosic substances. Thermogravimetric evaluation and the use of differential scanning calorimetry studies demonstrated in which the CNC is very thermally stable. The scanning electron microscopy indicated that chemical pretreatments decreased lignin and hemicellulose, whereas hydrolysis generated CNC with a rod-like shape (Mohsin Raza *et al.,* 2022).

3.4 Pineapple peel

Cellulose was isolated from pineapple peel (*Ananas comosus*) (Bromeliaceae). The raw material is the pineapple peel of the fresh fruit. These residues are washed to remove colors, lipids, and hemicelluloses, and then subjected to a bleaching-delignification process for 4-6 h. All resulting products were characterized for lignin, hemicellulose, cellulose and ash content using standard methods. The final dry matter content is lower than the raw material. The process produces pure cellulose with low levels of lignin and hemicellulose, especially during 6 h bleaching. The purified cellulose was subjected to acid hydrolysis to remove nanocrystals, and the testing time was 30 min to 60 min. These cellulose nanocrystals have small size (<1000 nm), high conductivity, and negative zeta value. Using a 6 h bleaching process during the purification process has proven to be better than 4 hrs. Pineapple peel proved to be a good source of cellulose for the production of cellulose nanocrystals (Ana Raquel Madureiraa and Tugba Atatopraka, 2018).

3.5 Corn husk

Corn (*Zea mays* L.) is a cereal crop belonging to the Poaceae grass family, reported to contain hemicellulose made up (67.9%) of the fiber, followed by cellulose (31.4%) and lignin (0.7%) (Bhuneshwari Rohilla and Sury Pratap Singh, 2022). Cellulose nanocrystals (CNCS) were isolated from corn husk by alkali and bleach followed by sulfuric acid hydrolysis. Morphological evaluations were done using SEM, and TEM. The use of FTIR spectroscopy demonstrated the elimination of non-cellulosic compounds. The crystallinity of corn husk and CNCS was also examined using X-ray diffraction analysis (XRD). In this study, the highest crystallinity index value of cellulose nanocrystals is 68.33% (Piyaporn Kampeerapappun, 2015).

3.6 Jack fruit peel

Cellulose was extracted from the non-eatable sections of jackfruit (*Artocarpus heterophyllus*) (Moraceae). The application of sodium chlorite treatment yielded the most cellulosic generation among each of the studied processes. Peaks in the CP/MAS ^{13}C NMR spectra and FT-IR wavelengths suggest an abundance of á-cellulose and lacking other important organic constituents such as hemicellulose and lignin. An X-ray diffraction investigation found an significant crystalline structure of 83.42%. An effective endothermic spike at 323^{0}C in DSC and TGA disintegration rates extending from 310 to 420^{0}C confirms the presence of cellulose (Trilokesh and Kiran Babu Uppuluri, 2019).

3.7 Lemon seed

Cellulose was obtained using Lemon (*Citrus limon*) (Rutaceae) seeds, a typical farm waste, employing a combination of sulfuric acid hydrolysis, the use of ammonium persulfate oxidative, and TEMPO oxidative. The characteristics of cellulose nanocrystals were compared using the methods of FTIR, the use of XPS, XRD, thermogravimetric evaluation, and the use of an AFM, and their use in pickering emulsions was examined as well. This study indicated that irrespective of the extraction process, all CNCS maintained the cellulose 1β pattern and diffused effectively (Huan Zhang *et al.,* 2020).

3.8 Apple pomace

Cellulose nanocrystals were created using cellulose derived from apple pomace (*Pyrus malus*) (Rosaceae). During the alkaline process part of cellulose extraction procedure, three different factors were adjusted using the approach known as response surface methodology (RSM). Maximize productivity, integrity (α-cellulose), and whiteness indices by adjusting sodium hydroxide content (6-12%), time required for extraction (30-240 min), and temperature (30-90°C). The best conditions were 10.23% sodium hydroxide, 69.82°C, as well as 161. 54 min, giving in a cellulose output of 27.96 ± 0.78%, α-cellulose composition of 85.31 ± 0.91%. Acid hydrolysis and ultrasonic treatment were used to make cellulose nanocrystals from cellulose. The morphology of the CNCs exhibited a needle-like structure having dimensions of 7.9 ± 1.25 nm and length of 28 ± 2.03 nm (Arzu Yalçýn Melikoðlu *et al.,* 2019).

3.9 Cassava peel

Cellulose was isolated from Cassava peel (*Manihot esculenta*) (Euphorbiaceae), by hydrolyzing with sulfuric acid to produce nanocellulose. Alkali treatment and bleaching are the most effective procedures for extracting cellulose from cassava peels. The final amount of cellulose from this process was 17.8% of dried Cassava peel, nitric and sulfuric processes yielded 10.78% and 10.32%, respectively. Hydrolysis was carried out at 50°C for 2 h. The post-treatment reaction byproducts from each stage of the procedures were analyzed. The use of Fourier transform infrared spectroscopy demonstrated the eradication of non-cellulosic components. XRD (X-ray diffraction) investigations indicated that cellulose's clarity improved after breakdown (Widiarto *et al.,* 2017).

3.10 Coconut husk fibres

Microcrystalline cellulose (MCC-C) was isolated from coconut husk (*Cocos nucifera*) (Arecaceae) fibres. To remove hemicellulose, sieved coconut shell fibers were dewaxed with sodium hydroxide (NaOH) and then acidified with sodium chlorite ($NaClO_2$) to remove additional lignin. The resulting lignin-free cellulose is then treated with potassium hydroxide. Solubility testing, X-ray diffraction patterns (XRD), thermogravimetric analysis (TGA), and scanning electron microscopy (SEM) were used to compare MCC-C with commercial grade microcrystalline cellulose (MCC). XRD analysis showed that the chemical treatment increased the crystallinity of MCC and MCC-C by 80.15% and 71.8%, respectively. TGA determines the removal of lignin hemicellulose, and the thermal stability of the product should be approximately 350-500°C and 300-500°C, respectively. Fiber morphology shows that the coconut fiber cross-section is irregular, the surface is uneven, there are many small microfibers, and there are some diseases on the surface. The results showed that microcrystalline cellulose could be separated from coconut shell fibers and used further (Nur Athirah Abdullah *et al.,* 2021).

3.11 Tomato pomace

Cellulose was isolated from Tomato pomace (*Solanum lycopersicum*) (Solanaceae) utilizing successive chemical hydrolysis in combination with mechanical pretreatment through high-pressure homogenization (HPH). The chemical and auxiliary highlights of cellulose isolated from Tomato pomace pretreated by HPH were compared with cellulose isolated from untreated Tomato pomace through light scrambling for molecule size dispersion, optical and checking electron microscopy, and Fourier-transform infrared spectroscopy (FT-IR) investigation. HPH pretreatment (80 mpa, 10 passes) not as it were advanced a slight increment within the abdicate of cellulose extraction (+9%), but contributed to straightforwardly getting defibrillated cellulose particles, characterized by smaller irregular domains containing elongated needle-like fibers (Annachiara Pirozzi *et al.,* 2022).

3.12 Cucumber peels

Cellulose was isolated from Cucumber peel (*Cucumis sativus*) (Cucurbitaceae), by treating with acid, alkali, and bleaching to separate the cellulose. The cellulose was then acid hydrolyzed (60% H_2SO_4) at 45°C for 45 min to produce cellulose nano crystal suspension, which was ultrasonically treated for 10 min to produce a suspension. The effects of ultrasonic therapy including the methods of dynamic light scattering and atomic force microscopy were utilized to study the outcomes of every treatment; the microstructural modifications, thermal features, and crystallization properties of the fibers have been examined by the use of scanning electron microscopy, thermogravimetric analysis, and X-ray diffraction extracted from acid-hydrolyzed cucumber peel, is rod-like in shape and possesses great crystallinity (74.1%), substantial heat durability with a decreased zeta potential (Sai Prasanna *et al.,* 2020).

3.13 Orange peels

Cellulose is extracted and retained from orange peel (*Citrus aurantium*) (Rutaceae) by antacid treatment, followed by fading. Orange peel-derived cellulose (OPDC) was analyzed and compared to microcrystalline cellulose. The FTIR analysis confirmed the assimilation of OPDC and MCC cellulose crests. DSC analysis revealed that MCC has greater heated solidity than OPDC. In addition, FESEM and molecule estimation investigations revealed a small amount of OPDC following pretreatment. The crystallinity index (cri) of OPDC was 80.14% greater than that of virgin OP (23. 54%). The arrangement handle is used to create biodegradable mixture films having various weights of OPDC, MCC, and polyvinyl alcohol (PVA). According to the FTIR range, the changes in the typical absorption bands and escalated band seen within the range of the PVA/OPDC mix film are equivalent to those of the PVA/MCC mix film. This confirmed the structure of current intermolecular and intramolecular hydrogen bonds, as well as conformational shifts between PVA and cellulose (Vanessa *et al.,* 2021).

3.14 Pineapple leaves

Ananas comosus (Pineapple) from the family Bromeliaceae contains 79-83% cellulose, 19% hemicellulose and 5-15% lignin (Manickavalli *et al.*, 2022). Cellulose nanocrystals are extracted from pineapple leaves using acid hydrolysis at 45°C for 5, 30, or 60 min, utilizing 20 ml of H_2SO_4 (9.17 M) per gram of product. Outcomes of cellulose small crystals, involving the crystallinity index, Fourier-transform infrared spectroscopy, morphological (shape as well as size), along with resistance to heat was found. The ideal extraction period for hydrolysis processes is 30 min. Following extraction, nanocrystals of cellulose provide needle-like particles that have great crystalline structure, a standard measurement being 249.7 ± 51.5 nm, and intersecting patterns at 4.45 ± 1.41 nm. The L/D proportion is around 60. As a consequence, PL-produced nanocrystals made from cellulose might be employed as supporting elements in nanocomposite material manufacturing (Roni Marcos dos Santos *et al.,* 2013).

3.15 Soy hulls

The work investigates the use of soy hulls (*Glycine max* (L.) Merr.) (Fabaceae) as a cellulosic substrate for producing nanocrystals through acid breakdown. The process of breakdown took place at 40°C for a period of 30-40 min, utilizing 30 ml of sulfuric acid (64% per gram of cellulose). The derived nanoparticles were identified by their crystalline structure, form, charge distribution on the surface, and heat stability parameters. The results indicated that the more extreme hydrolysis circumstances (40 min) generated shorter nanocrystals and damaged the crystallized nature of the cellulose. After thirty minutes of the extraction procedure, the tiny crystals exhibited an elevated crystanallity (73.5 %), with a typical dimension of 122.66 ± 39.40 nm, an average size of 2.77 ± 0.67 nm, has an aspect ratio of around 44, making them suitable to be utilized as reinforcement in nanocomposite formulations (Wilson Pires Flauzino Neto *et al.,* 2013).

3.16 Lotus leaf stalk

Chemical pretreatment and high-intensity ultrasonication were used to successfully produce nanofibrillated cellulose (NFC) from lotus leaf stalks (*Nelumbo speciosa*) (Nelumbonaceae). The techniques of optical microscopy and Morfi fiber analyzer were used to determine the morphological features of chemically pure lotus leaf stalk cellulose microfibrils. The use of FTIR spectroscopy revealed that non-cellulosic components had been extensively removed following chemical processing. The transmission electron microscopy also called TEM studies shown that produced each NFCS measured 20±5 nm in width and microns in length combined as a network like arrangement. The x-ray diffraction assessment revealed that final form of nanofabrillated cellulose has an cellulose type 1 crystalline form with an extremely strong crystallinity (70%). The nanofabrillated cellulose began to deteriorate at a temperature of 217^0C, with the greatest degree of disintegration occurring at 344^0C (Yandan Chen *et al.,* 2014).

3.17 Mango tegument

Mango tegument (*Mangifera indica*) (Anacardiaceae) has a high cellulose content, making it an ideal raw material for the development of single-use goods or biopolymer blends. To make cellulose pulp, the mango tegument was chemically treated using typical alkali and acid procedures. These teguments were treated with sodium hydroxide solutions at 80°C for up to 2 h or acetic acid solutions at 60-70°C for a period of 1 to 2 h. Following treatment, the yield, colour, chemical examination, structural, thermal, and morphological features have all been evaluated. The alkaline methods produced pale-colored cellulosic pulp with a typical yield of 37-42% and decreased hemicellulose percentage (Maribel García-Mahecha *et al.,*2023).

3.18 Chilli stalk

Extraction of cellulosic biopolymers from chilli stalks (*Capsicum annuum*) (Solanaceae) provides a sustainable, compostable and cost-effective biological materials with many uses. The extraction method includes alkaline treatment (NaOH) and bleach (alkaline H_2O_2), resulting in 29.85% cellulosic biopolymer molecules. The obtained cellulose was then analyzed quantitatively and functionally and then characterized (FTIR analysis, XRD analysis, TGA analysis, DSC anaylsis, and SEM analysis) to assess its functional components, crystallinity, thermodynamic characteristics, and surface characteristics. Research activities are more profitable than the cellulose industry. The behaviour suggests that the chemical treatment removes organic substances which include hemicellulose, lignin, and pectin (Adhithya Sankar Santhosh and Mridul Umesh 2024).

3.19 Cashew nut shells

In the study, cashew nut shell (*Anacardium occidentale*) (Anacardiaceae) was utilized as raw materials in the manufacturing of natural cellulose. Cellulose was isolated from dewaxed CNS using modified acid hydrolysis with nitric acid (7% w/v), alkaline treatment (17.5% w/v NaOH) as well as 3.5% (v/v) sodium hypochlorite bleach solution (NaOCl). SEM, FTIR, and TGA were used for determining the micromorphology, chemical functional group, and thermal stability of crystallized cellulose specimens respectively. This means that the CNS might be recycled as an initial component for the manufacturing of cellulose-based fibers, which are utilized in packaging, reinforcement, and binders in various industrial purposes (Bamgbola *et al.,* 2020).

3.20 Banana pseudostem

Cellulose nanocrystals (CNCS) were isolated from raw banana pesudostem (*Musa acuminata*) (Musaceae) fibers in two steps: chemically purified cellulose (CPC) was produced, and CNCS were isolated from CPC using an acid hydrolysis approach. The impact of chemical treatments on the characteristics of prepared CNCS was studied. The influence of hydrolysis reaction time on the shape of cellulose nanocrystals was also investigated. During alkali treatment, some lignin and hemicellulose were extracted in addition to other extractives. FTIR examination of raw fibers revealed only peaks at 1730 cm^{-1} and 1250 cm^{-1}. It showed the elimination of lignin, hemicellulose, and waxes during pretreatment (Gaurav Zope *et al.,* 2022).

3.21 Tamarind seeds

Microcrystalline cellulose was isolated from Tamarind (*Tamarindus indica*) (Fabaceae) seeds in three stages: chemical alkalization, acid hydrolysis, and bleaching. The isolated microcrystalline cellulose was chemically, thermally, and morphologically investigated to confirm its cellulose contribution, heat resistance, and material compatibility. Physical factors such as density and yield % were evaluated to determine the lightweight utility and economic productivity. Microcrystalline cellulose has favorable qualities, including high cellulose content (90.57%), average density (1.561 g/cm^3), practicable average roughness (12.161 nm), acceptable particle size (60.40 ± 21.10 µm), good crystallinity (CI-77.6%), and heat stability (up to 230°C) (Divya Divakaran *et al.,* 2024).

3.22 Sesame husk

A 0.7% sodium chlorite solution was used to treat the dark brown sesame husk (*Sesamum indicum* L.) (Pedaliaceae), followed by an alkali treatment. The chemically treated material then underwent acid hydrolysis with 35% sulfuric acid. This process resulted in the separation of cellulose micro whiskers from the husk, yielding a white colloidal dispersion with a solid residue settled at the bottom. The micro whiskers were thoroughly examined using optical microscopy and transmission electron microscopy (TEM). It was observed that the micro whiskers were multidimensional, occurring in various related forms, and had a width ranging from 1 to 2 µm. To further refine the micro whiskers, they were homogenized, resulting in the formation of spherical cellulose nanoparticles (CNPS) with sizes ranging from 30 to 120 nm. The white cellulose nanoparticles and residue were subjected to analysis using X-ray diffraction, which revealed their highly crystalline nature. Furthermore, atomic force microscopy authenticated the spherical form of the cellulose nanoparticles (Bindu Sekhar Purkait *et al.,* 2011).

3.23 Millet husk

Nanofibers of cellulose (CNFS) isolated from millet husk (*Pennisetum glancum*) (Poaceae), a sustainable agro waste. To remove non-cellulosic components, a variety of pre-treatments were used, including mercerization, steam explosion, and peroxide bleaching (without chlorine). Whitened millet husk pulp were acid hydrolyzed, (5% oxalic acid) and homogenized to produce CNFS. The collected CNFS have been examined. Using a variety of methods, including FTIR, XRD, SEM, TEM, DLS, EDX, TG, DTG, DSC, and solid state ^{13}C NMR. The CNFS had a cellulose type-I structure, with a diameter of 10-12 nm and a crystallinity index of 58.5%. The existence of a distinct signal at 89.31 ppm in the solid state ^{13}C NMR spectra showed the presence of type-I cellulose in the CNFS. Furthermore, the CNFS had a T_{max} of 341°C, which was 31°C greater than the raw millet husk (Midhun Dominic *et al.,* 2022).

3.24 Rice husk

The nanofibers of cellulose of great crystalline structure as well as purity have been isolated from two indigenous rice husk (*Oryza sativa*) (Poaceae) kinds by a hydrothermal method, Acid-alkali treatments are then utilized accompanied by mechanical disruption. The CNFS extracted exhibited an average diameter of approximately 35 nm. TGA along with DTG spectra revealed that the CNFS had high thermostability. The CNFS exhibited a strong photoluminescence peak at 404 nm and a high quantum yield (about 58%). This is the first publication on nanocellulose's inherent fluorescence properties in the absence of a coupled fluorescence molecule/dye. The CNFS also displayed good hemocompatibility in the hemolysis test, indicating their potential for biological applications (Kalita *et al.,* 2015).

3.25 Peanut shells

Microcrystalline cellulose (MCC) and nanocellulose (NC) were isolated from peanut shell (PSP) (*Arachis hypogaea*) (Fabaceae), a major agricultural waste. Microcrystalline cellulose was isolated owing to its prospective relevance in the pharmaceutical business using alkaline treatment followed by bleaching, and nanocellulose was isolated from microcrystalline cellulose using acid hydrolysis. The changes in functional groups and crystallinity of the cellulose samples throughout various phases of isolation were assessed using FTIR and X-ray diffraction techniques, respectively. The FTIR spectra indicated hemicellulose and lignin. Had been entirely removed. The XRD pattern revealed that the isolated microcrystalline cellulose is crystalline in form. The size distribution of freeze-dried nanocellulose was measured using DLS. The average diameter of the nanocellulose sample was also calculated (Rani Krishnan Punnadiyil *et al.,* 2019).

3.26 Pharmaceuticals from agro waste

Waste from the agriculture and food industries has the potential to boost the body's absorption of a wide variety of pharmaceuticals. These are a fantastic resource for a variety of essential nutrients as well as phytochemical substances that can help contribute to a balanced diet. They are a good source of organic and inorganic compounds, sugars, and many phenolic compounds.

3.26.1 Antibiotic production

Various agricultural byproducts are utilized in the synthesis of various antibiotics. The peanut shells proved to be the most productive substrate for the production of antibiotic tetracycline at 4.36 mg/g, followed by corncobs (Asagbra *et al*., 2005). The synthesis of extracellular rifamycin B was studied through the use of solid-state fermentation with oil-pressed cake, which is regarded as an agro-industrial waste (Vastrad and Neelagund, 2011). An investigation was made into the process of solid-state fermentation used by *Streptomyces speibonae* OXS1 to create oxytetracycline from cocoyam peels, which are considered to be household kitchen wastes of agricultural output (Ezejiofor *et al.,* 2012).

3.26.2 Antioxidant properties

Antioxidant and anticancer drugs were also developed using agro waste as a substrate. The remains of various fruits and vegetables, such as fruit and vegetable peels, are usually referred to as waste or useless. The ellagitannins, punicalagin, and punicalin, which are extremely powerful antioxidants were obtained from pomegranate peel waste. Phenolic chemicals play a particularly important role among them because of the widespread knowledge of their positive effects on human health, including their function in cancer and cardiovascular disease prevention (Jimenez Lopez *et al.,* 2020).

3.26.3 Antibacterial and anticancer properties

Chlorogenic acid is the most abundant phenolic acid in peels. Byproducts of lignocellulosic agriculture, such as wheat straw residues, wheat and rice bran, spent residues of coffee ground nuts, and sawdust, have been widely described as a clean source of phenolic compounds and have the potential to be utilized for application in a variety of industries due to the antioxidant and antimicrobial properties that they possess (Fermoso *et al.,* 2018).

4. Conclusion

The development of naturally derived excipients is now attracting considerable attention. Polymers serve a crucial role in medicine delivery. Choosing the correct polymer is critical for pharmaceutical manufacturing. Plant-derived polysaccharides include gums, pectin, cellulose, and alginates. Herbal excipients are potential biodegradable materials that can be compatible chemically with excipients used in medication delivery systems. In addition, herbal excipients are non-hazardous readily accessible, and they're less costly than artificial counterparts.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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