(RESEARCH ARTICLE)

Quantitative determination of cellulose content of peels of selected plants growing in Enugu Urban

Enem Chukwudike Eric [1], Chikezie Kenechukwu Cosmas [2], Adeoye Kayode Abiodun [3], Babarinde Taofeek Olajide [4, *], Ifeanyichukwu Blessed Chisom [5] and Ezenwa Nwaeze Franklyn [6]

[1] Student/ Graduate Assistant, Department of Chemistry and Biochemistry, College of Art and Science, Lamar University, P.O. Box 10022 Beaumont, Texas 77710, USA.

[2] Student/ Graduate Assistant, Department of Chemistry and Biochemistry, Lamar University, P.O. Box 10022 Beaumont, Texas 77710, USA.

[3] Department of Chemistry and Biochemistry, Lamar University, P.O. Box 10022 Beaumont, Texas 77710, USA.

[4] Department of Agricultural Economics, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria.

[5] Department of Biochemistry, Faculty of Biological Sciences, Imo State University, Owerri, Imo State, Nigeria.

[6] Department of Chemistry and Biochemistry Lamar University, P.O. Box 10022 Beaumont, Texas 77710, USA.

Abstract

Recycling agricultural waste into industrial raw materials can lessen pollution in the environment and encourage entrepreneurship among the increasing number of unemployed life science graduates. This study created cellulose from plantain and cassava peels that had physicochemical characteristics similar to those of cellulose that are made commercially. For 16 hours, 90% ethanol was used to defat the powdered cassava and plantain peels (CPP and PPP, respectively), with sporadic shaking using a mechanical shaker set to 150 rpm. Every defatted PP was dried for seven hours at 800C in a hot air oven. Deproteination was accomplished by soaking in 1mol of NaOH solution at a PH of 11.6 for 24 hours at a ratio of 1.10w/v (100g PP/1000ml). For three hours, the deflated and deproteinated PPP and CPP were immersed in 15% hydrogen peroxide. Hausner's Quotient of CPC and PPC, bulk density, packed density, hydrated density, emulsifying activity, and water and oil retention capabilities were all examined. For CPP and PPP, the peel powders have crude fat concentrations of 3.20% and 2.18%, respectively, and protein contents of 4.50% and 3.85%. The bulk densities of CPC, PPC, and CC are 0.52, 0.55, and 0.21, respectively, while their packed densities are 0.68, 0.73, and 0.28. The CC (1.98) has a lower water retention capacity (WRC) than the CPC (3.09) and PPC (2.96). The ORC of 3.23 for the CC was higher than that of the PPC and CPC (0.11).

Keywords: Quantitative determination; Cellulose content; Peels; Selected plants; Enugu Urban; Cellulose analysis; Plant peels; Biomass

1. Introduction

Wastes derived from agricultural products are known as agricultural biomasses. Most commonly, biomass refers to plants or plant-based materials—specifically, lignocellulose biomass—that are not utilized for food or feed. The processing industry and pollution monitoring organizations have challenges due to the seasonality and high perishability of agricultural biomass. (Emaga and others, 2006). Methane and leachate are released by rotted agricultural biomass, and carbon (IV) oxide (CO_2) and other pollutants are produced when farmers burn their land in the open (Heinimo, J. et al, 2009). Therefore, poor handling of agricultural biomass waste is causing local air pollution, water and soil contamination, and climate change. Around the world, biomass is a renewable alternative energy source.

---

* Corresponding author: Babarinde Taofeek Olajide

Forests, plant waste, and agricultural crops are examples of biomass resources. Horticultural and arable field crops have yielded a number of leftovers during the agricultural production of fruits and vegetables. Energy policies and planning that ensure global food security should support the use of biomass for energy at the local, national, and international levels (Avcıoğlu et al., 2019).

One of the primary fruit crops cultivated in Nigeria is plantains, or Musa Paradisiaca, which is one of the top producers in the world. Plantains are used mostly unripe, their flesh is starchy rather than sweet, and it needs to be cooked. They look like bananas that haven't ripened. Thirty percent of the fruit is the peel, the main by-product. This by-product is hazardous to the environment because of its high water content, which leaves it open to microbial modification, as well as its high levels of nitrogen and phosphorus. Plantain peel flour might offer a new product with a specific composition for a variety of domestic and commercial uses, claim Emaga et al. (2007). The process of making plantain peel flour, how the ripeness stage affects the plantain peel's pectin, and nutritional fiber components.

Nigeria has a large plantation of cassava (Manihot esculenta), a woody shrub that is a member of the spurge family (Euphorbia cease). It is commonly planted as an annual crop in tropical and subtropical nations due to its edible starchy tuberous root, which is a substantial source of carbohydrates. Fifty million tonnes of cassava are produced annually in Nigeria by about three million households, the majority of which are women. About 14 million tonnes of the crops' by-products, such as peels and undersized tubers, are discarded as waste, whereas the majority of the crops are used for human use (International Institute of Tropical Agriculture, IITA, 2016). Cassava peels are higher in protein and cyanogenic glycosides than other tuber portions (Tewe, 2014). Cassava peels have three main disadvantages: they spoil quickly, contain a lot of phytate, and contain cyanogenic glycosides. The processing of cassava generates a lot of trash and is widely thought to be a major cause of environmental degradation.

In Nigeria, cassava waste is typically burned or allowed to decompose, making room for more waste heaps to form. According to Aro et al. (2010), the heaps produce a strong, unpleasant odor and release carbon dioxide. Large concentrations of cyanogenic glucosides found in cassava peels have the potential to pollute surface waters, particularly if they are stored in areas that receive a lot of rain or are just dumped in surface waters.

Since cellulose makes up the bulk of plant cell walls worldwide, it is currently the most well-known and prevalent dietary fiber. The polymer of anhydro-β-d-glucopyranose units, cellulose, is favored by β-1,4-glycosidic linkages. Cellobiose, cellotriose, and cellotetraose are the dimers, trimers, and tetramers of cellulose's oligosaccharides, also referred to as cellodextrins. Each bundle of fibers in cellulose has hydrogen bonds, which provide it strength and resistance to chemical and biological hydrolysis (Dhingra et al., 2012). It can absorb a large amount of water molecules, making its water-holding capacity one of its noteworthy characteristics. Because the enlarged cellulose makes the body feel fuller, it can help with weight control.

To optimize the health benefits of cellulose, its solubility is increased through enzymatic and chemical modifications. One of the byproducts of the hydrolytic breakdown of cellulose is glucose, along with cellodextrins and shorter-chain cellulose polymers. To make cellulose products more pure, partial purification is necessary. The potential of water-soluble cellulose as a fermentable fiber is being investigated further. Recent research indicates that small cellulose molecules can promote the growth of probiotics (Nsor-Atindana et al., 2020). The study also discovered a small amount of cellulose that was very soluble in water, suggesting that it may have prebiotic qualities. The goal of the study was to address the growing need for functional food fibers by examining the potential of cellulose modification. The goal of the study was to increase cellulose's solubility by using hydrolytic techniques. The inquiry was centered on evaluating the capability of soluble cellulose and cellodextrins to function as prebiotics and serve as carbon sources for probiotics.

1.1. Statement of the Problem

According to the survey released by the United Nations Development Program, solid waste disposal problem was ranked as the second most urgent urban challenges surpassed only by unemployment and followed by poverty (Agagu, 2008). In Nigeria, the peels constitute sizable portion of solid wastes with negative environmental implications, however, few types of research have been reported on the utilization of cassava peels as raw materials for application in industries, especially in production of cellulose of food or pharmaceutical grades. Recycling of these peels into economically viable products will mitigate environmental hazards associated with them and add values to the cassava and plantain products. Production of cellulose from the peels is one of the many ways to solve the problem of peels environmental pollution, and improve energy structure and agricultural development.

Aim and Objective

The aim of the study is comparative evaluation of some physicochemical properties of cellulose prepared from two different agricultural biomass (cassava and plantain peels).

1.2. Specific objectives

The specific objectives are

- To produce cellulose from cassava peel.
- To produce cellulose from plantain peel.
- To compare some physicochemical properties of the cellulose produced with those of the commercial cellulose.

1.3. Significance of the Study

Tonnes of Agricultural wastes are discarded in the environment. To recycle the randomly discarded agricultural waste, give value to them which can be essential for commercial and industrial purposes and drastically reduce environmental pollution, promote entrepreneurial opportunities to the teaming unemployed graduates of the life sciences and enhance public health

---

2. Literature Review

2.1. Agricultural Biomass

Waste derived from agricultural products is known as agricultural biomass. Most commonly, biomass refers to plants or plant-based materials—specifically, lignocellulose biomass—that are not utilized for food or feed. The processing industries and pollution monitoring organizations face challenges due to the seasonality and high perishability of agricultural biomass. During agricultural crop production, biomass residues and crop yield are directly correlated. The more crops produced, the more crop residues there are because they comprise a certain percentage of the crop. The leftovers from the cutting and pruning of stems, straws, stalks, leaves, branches, and other agricultural materials after the main crop harvest are the biomass residues that are being discussed here. One can determine the biomass energy potential by knowing these parameters. Crop yield, biomass residues, and their agronomic development are also impacted by environmental factors such as soil and climate (Avcıoğlu et al., 2019). Making agricultural waste into a resource that can be used rather than simply thrown away should be the goal. The main ways that agricultural wastes can improve food security are by producing energy, using them as animal feed, and using them as soil amendments and biofertilizer. Many of them are risk-free when added straight to the soil and contain significant amounts of organic matter.

The conversion of agricultural wastes, such as crop residues and animal manures, into organic fertilizers (through composting) is one of the waste treatment technologies that makes it possible to use organic waste as fertilizer, even in populated areas. Technology is crucial to increasing soil fertility and, in turn, crop productivity (Hargreaves et al., 2008; Sabiiti et al., 2011). In the majority of Africa, where a lack of nutrients poses a significant barrier to food production, the use of organic fertilizers is especially crucial (Sabiiti et al, 2011). Additionally, composting eliminates pathogens, lowers weed germination in agricultural fields, eliminates odors, and reduces the volume of waste, all of which help to address major environmental issues related to the disposal of large amounts of waste. The compost can be utilized on the same farm or sold to generate extra income. Additionally, the growing demand for organic products like maize and goat meats has led to an increase in the production of compost for agricultural use (Sabiiti et al, 2011).

Animal waste and crop residues can both be utilized as animal feed. However, the kind of feed, bedding material, and animal species all affect how nutrient-rich the waste is. A common practice in cattle feeding is the use of broiler litter. It is important to remember that animals, particularly ruminants, can help reduce potential pollutants by turning crop residues into food. The only microbial enzyme capable of breaking down cellulose, the most prevalent plant product, is found in the rumen (Sabiiti et al. 2011). Nutrients in byproducts are used by ruminants and do not cause waste disposal issues (Sabiiti et al. 2011).

Different regions of the world have used agricultural waste to produce energy to differing degrees (Tumuhairwe et al., 2009). In addition to making money from the energy generated, waste-to-energy projects provide a different and sustainable way to dispose of waste. Furthermore, a valuable by-product of the schemes is a high-quality, almost odorless agricultural fertilizer. Anaerobic digestion is becoming more and more popular as a renewable energy source due to worries about future energy shortages and the rising prices of conventional fuels and the electricity produced

from them. Due to the massive amount of waste generated by cassava processing facilities in Nigeria and the potential for catastrophic environmental effects, appropriate management and release of these wastes.

Agricultural wastes can be a useful resource for increasing food security, but if they are not handled, stored, or disposed of appropriately, they may pollute the environment or even endanger human health (Sabiiti et al., 2011). This necessitates raising public awareness of the advantages and possible risks associated with agricultural waste, particularly in developing nations.

2.2. Plantain (*Musa Paradisiaca*)

Nigeria is one of the world's top producers of plantains (Musa Paradisiaca), a major fruit crop. Plantains are bigger and have starchy flesh, much like unripe bananas. 30% of the fruit is made up of the peel, a primary by-product that presents environmental problems because of its high water, phosphorus, and nitrogen content, which makes it vulnerable to microbial modification. According to Emaga et al. (2007), plantain peel flour offers the possibility of producing standardized goods for a range of commercial and residential uses. In addition to a thorough review of banana and plantain cultivars with an emphasis on Pacific Island cultivars (Ploetz et al., 2007), research has examined value addition to plantain peel, including flour production and the effect of ripeness on dietary fiber and pectin content (Emaga et al., 2008).

2.3. Use of Plantain Peels

With a production of over 165 million tonnes in 2011, plantains are a fruit that is consumed all over the world. Once peeled, the fruit can be eaten raw or cooked, but the peel is usually thrown away, adding significantly to organic waste (FAOSTAT 2011). In some areas, especially on small farms that grow bananas, plantain peels are used as feed for a variety of animals, such as cattle, goats, pigs, monkeys, poultry, fish, and zebras. But there are issues with the peels' tannins and how they affect the health of the animals (Heuze et al., 2017). Plantain peels' nutritional makeup varies depending on the cultivar and maturity; for example, they have less fiber than dessert plantain peels, and as they ripen, their lignin content rises from 7% to 15% dry matter. Peels from plantains typically make up 6-9% dry matter of protein and 20-30% fiber (measured as NDF). Green plantain peels have 40% starch, which converts to sugars upon ripening.

Water purification (A. Chaparadza et al., 2012), ethanol production (Oberol et al., 2011), cellulose extraction (Hai-Yan Sun et al., 2011), lactase production (N. Pareek et al., 2011), fertilizer, and composting are just a few of the many uses for plantain peels outside of animal feed (F. Kalemelawa et al., 2012).

2.4. Peeling method

Enzymatic and chemical techniques are used to alter the solubility of cellulose in order to increase its health benefits. The general hydrolysis of cellulose results in the production of glucose, cellodextrins, and different kinds of shorter-chain cellulose polymers. Partial purification is necessary to produce more pure cellulose products. Further research is being done on the use of water-soluble cellulose as fermentable fiber. A small amount of cellulose can help probiotics grow, per a recent study (Nsor-Atindana et al., 2020). But according to the study's findings, the small amount of cellulose was highly soluble in water, suggesting that it might have prebiotic properties.

2.5. Cassava (*Manihot esculenta*)

Because of its starchy tuberous roots, which are an important source of carbohydrates, cassava (Manihot esculenta), a woody shrub of the Euphorbiaceae family, is widely grown in Nigeria as an annual crop in tropical and subtropical regions. Fifty million tonnes of cassava are produced annually in Nigeria by about three million households, most of which are made up of women. About fourteen million tonnes of by-products, such as peels and undersized tubers, are thrown away as waste even though humans eat the majority of the crop (International Institute of Tropical Agriculture, 2016). Although cassava peels have a higher protein content and cyanogenic glycoside content than other tuber parts (Tewe, 2014), they have three major drawbacks: they spoil quickly, they contain phytates, and they have a high cyanogenic glycoside content. Processing cassava produces a lot of waste, which greatly contributes to pollution in the environment.

To make room for more waste, cassava waste in Nigeria is frequently burned or allowed to decompose, which releases carbon dioxide and has a strong odor (Aro et al., 2010). Because they contain high levels of cyanogenic glucosides, cassava peels can pollute surface water, particularly when they are left out in the rain or dumped in bodies of water. Peeling and washing the tubers mechanically yields waste peels, which make up around 15% of the root (Aro et al., 2010) (Otache et al., 2017). The tubers may be harmed by improper handling during harvest (Otache et al., 2015). The periderm, cortex, and pulp are the three separate layers visible in a transverse section of the cassava root (Wheatley et

al., 2008; Otache et al., 2017). Cassava roots are comparatively rich in vitamin C and contain significant amounts of minerals such as calcium, phosphorus, and iron (Otache et al., 2017). Nevertheless, the hydrocyanic acid content of cassava peels, which can impede growth and development, limits their use as feed for non-ruminant animals (Apata et al., 2012). To increase cassava's feeding value, processing methods like sun-drying, parboiling, soaking, and retting have been used (Ekwe et al., 2011; Ooye et al., 2014). Smallholders in Nigeria who use the leftover cassava peels to raise goats have begun to pay more attention to drying them on black plastic sheets (Adebayo et al., 2008).

Garri and starch processing facilities generate the majority of the waste from cassava processing, and it won't be useful until the peels can be used to make animal feed. Reducing the cost of raising cattle and addressing the issue of their waste disposal are two benefits of using cassava peels for animal feed. Processing results in the production of large quantities of liquid pulp and cassava peels (Jideofor et al, 2015). Most of these wastes are used as animal feed, though some become solid municipal waste (Adesanya et al, 2008). Furthermore, the liquid residue that remains after processing cassava can be gathered and converted into bioethanol, and the muck deposits that result can be utilized as manure to raise the nutrient value of the soil.

Natural fibers made from wood, annual plants, and agricultural waste are primarily composed of cellulose. Cellulose is a plentiful, sustainable resource. In a single plane, the chains are made up of β-D-glucopyranose units connected by 1-4-glycosidic bonds (Fig. 1.1). According to Moran et al. (2008), cellulose is a linear polymer (Fig. 1.2). There are three OH groups in every glucose ring, which are the functional groups found in cellulose chains. Depending on where the OH groups are located at the glucose unit, cellulose molecules can form two different kinds of hydrogen bonds. Intramolecular and intermolecular hydrogen bonds are two different kinds.
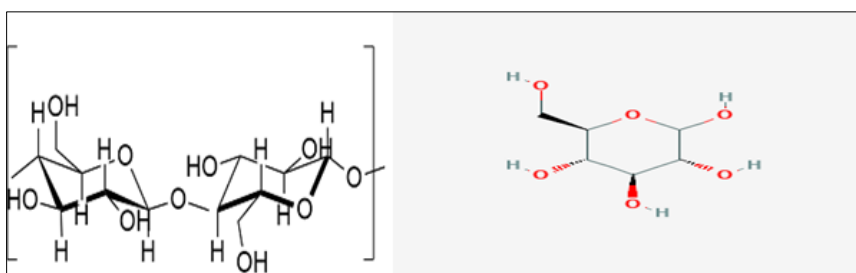

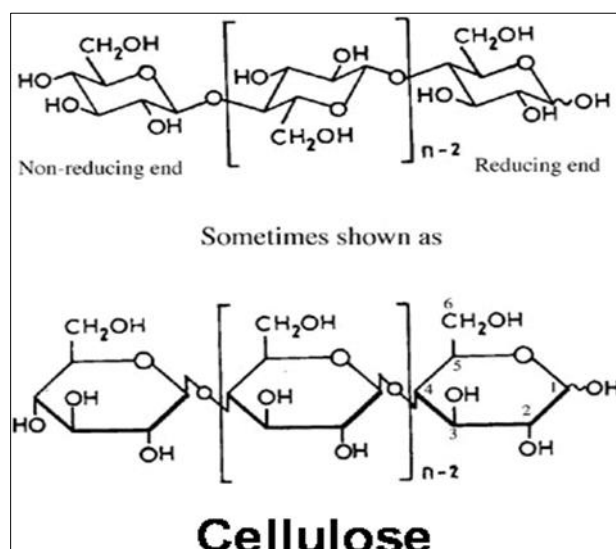**Figure 1** Cellulose and D-glucose

Figure 2 Cellulose molecules

Both crystalline and amorphous regions are created when cellulose molecules group together. The crystalline areas are inaccessible to water due to their highly ordered structure, which is preserved by hydrogen bonds. The notable elastic modulus of native cellulose fibers, approximately 150 GPa, is primarily due to the extended chain structure of crystalline cellulose. The longitudinal tensile strength of crystalline cellulose is approximately 10 GPa. The degree of polymerization of cellulose, a naturally occurring polymer, is roughly 10,000 glucopyranose units in wood and 15,000

in cotton. Cellulose comes in three different varieties: cellulose I, also known as native cellulose, cellulose II, cellulose III, and cellulose IV. Native cellulose and cellulose II differ in two significant ways despite their many similarities. First, cellulose II has a "anti-parallel" chain direction arrangement and a staggered, antiparallel center chain (Granstrom 2009).

Along with antiparallelism, one of the hydrogen bonding patterns that is different from cellulose I is a clear hydrogen bond between the center chain and the distant corner chains between O2 and O2. Because cellulose II's crystal structure is more thermodynamically stable than native cellulose's, cellulose I can be transformed into cellulose II but not the other way around. Another cellulose allomorph, cellulose III, is produced when cellulose Iβ and cellulose II are treated with liquid ammonia or particular amines. According to Yui et al. (2010), cellulose III can return to its parent forms.
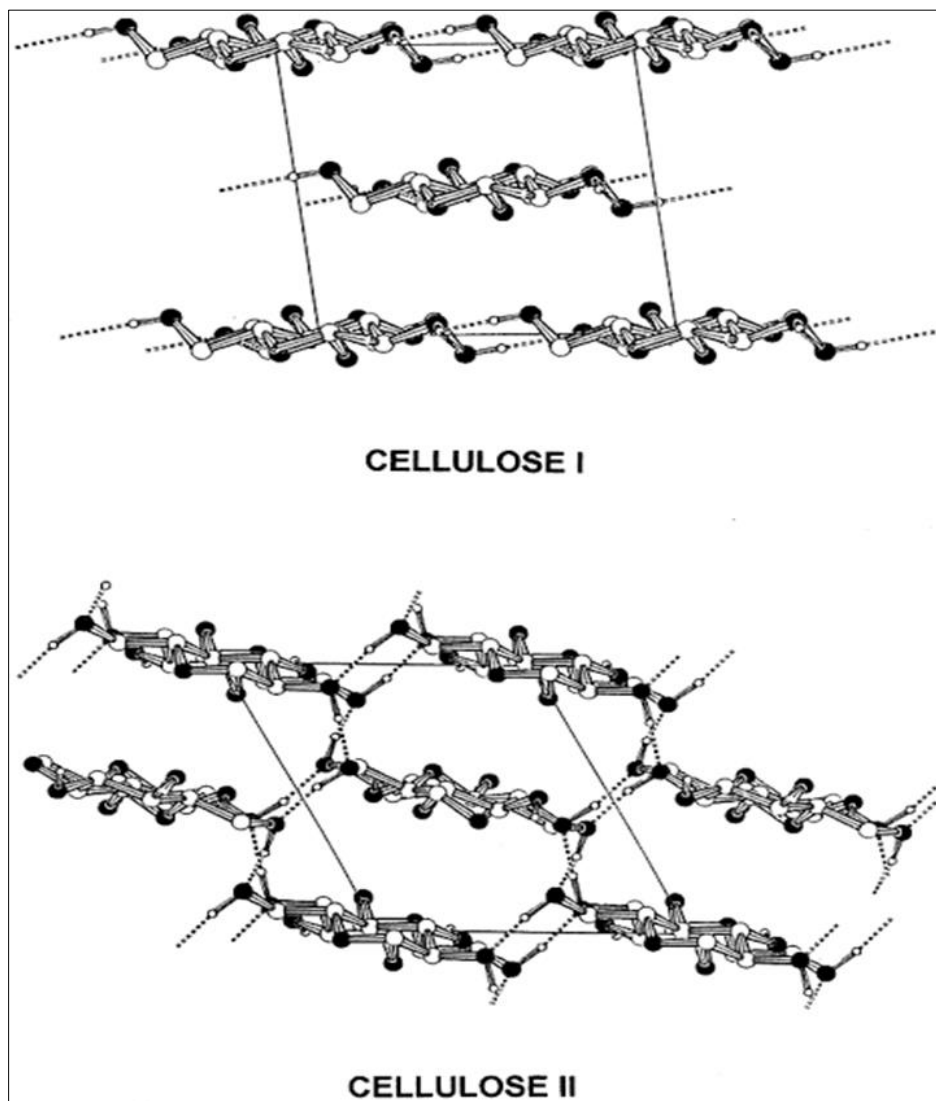

Figure 3 Cellulose structure of cellulose I and II

Most of the regenerated cellulose that is currently available to consumers is composed of cellulose II. Cellulose II can be made in a few easy steps. The most popular method is simple mercerization using a strong alkali solution. For instance, rayon fibers are widely used. They consist of a polymer of β-1,4-linked D-glucopyranose, in which no more than 15% of the hydrogen of the hydroxyl groups has been substituted by pigments, fire retardants, and manufacturing impurities. Usually, rayon fibers are used to make textiles. (Well and Levchik, 2008).
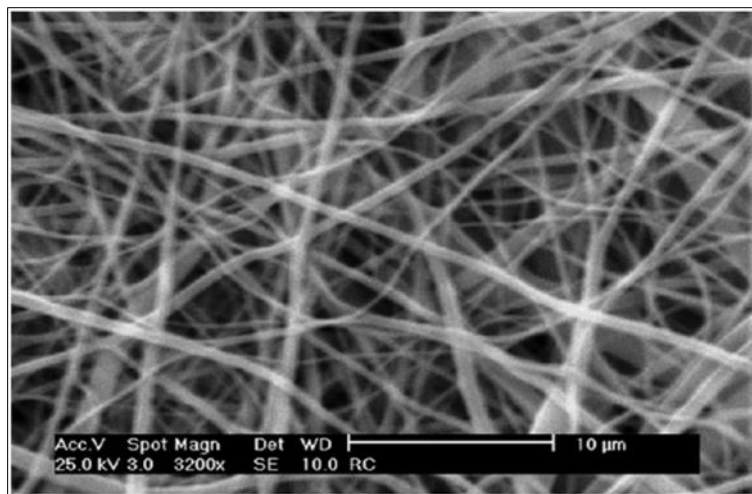
Figure 4 SEM image of regenerated cellulose (Ghorani et al., 2013)

2.6. Cellulose Remaking

Cellulosic fibers offer an enticing opportunity to reinforce petroleum-based polymers and bioplastics while also adding more bio-based material to petroleum-based polymers due to their biodegradable nature and relatively high mechanical qualities. However, there are still limitations on using cellulose fibers as a reinforcing agent. This restriction results from cellulosics' high hydroxyl group content, which makes them hydrophilic and incompatible with the polymer matrices' hydrophobic behavior. Because they are readily available in the plastics market and have low melting points, high density polyethylene (HDPE), low density polyethylene (LDPE), polyethylene (PP), and polyvinyl chloride (PVC) are the polymers most frequently filled with cellulosic fibers. The product's poor interface and low resistance to moisture adsorption are caused by the fiber/matrix incompatibility. The interface is actually one of the most important parts of the composites. The composite's resistance to failure can be increased by transferring load to it when the matrix phase and the dispersed (reinforcing) phase are sufficiently bonded.

Three techniques have been employed to distribute cellulose evenly and strengthen the interface between the thermoplastic matrix and the cellulose reinforcement: compatibilizing, grafting, and chemical modification. Compatibility testing uses a co-polymer that has a region that mimics the matrix polymer chemically and another that can interact with the hydroxyl groups of cellulose. One example is maleic anhydride polypropylene (MAPP) for composites made of natural fiber and polypropylene. Stark and Rowlands (2008) found that the composites produced with 3 weight percent MAPP added to natural fibers (fiber weight ratio: PP = 40:60) were roughly three times as stiff and twice as strong as the composite without MAPP treatments.

Using fibers, the second strategy, grafting, generates radicals that initiate the chain growth of polymers that complement the matrix polymers. For example, (Stenstad et al. 2008) used a cerium-induced grafting technique to add epoxy groups, carbon-carbon double bonds, cationic groups (amines), and anionic groups (carboxyls) to microfibriallated cellulose. They also demonstrated how grafting polymer brushes and layers can hydrophobicize cellulose. These results imply that cellulose can form composites through interactions with a potentially wide range of matrix polymers.

The alternative tactic, chemical modification, involves changing the fibers' hydroxyl groups to a hydrophobic functional group in order to make them compatible with the hydrophobic matrix polymer. Acetylation and propionylation are two examples. For instance, acetylation causes cellulose to become hydrophobic by reacting with acetic anhydride and replacing the cell wall's hydroxyl groups with acetyl groups. (Li and others, 2007).

Polyethylene glycol (PEG) is also utilized in certain applications to alter the characteristics of cellulose. Water-soluble, lubricating, odorless, neutral, nonvolatile, nonirritating, and miscible with ionic liquid are all properties of polyethylene glycol. PEG is used to plasticize or alter cellulose in the field of food science. In medical engineering, electroactive papers are created by combining cellulose with polyethylene oxide (PEO) and polyethylene glycol (PEG). Cellulose nanowhiskers are dispersed in polylactic acid polymer using PEG in the nanocomposite field (Lijunberg et al., 2005). Furthermore, a strong alkali system was used to dissolve cellulose in PEG (Han and Young 2009). The cellulose that precipitated from the solution after washing was examined for the presence of residual PEG using thermogravimetric analysis (TGA) and dynamic scanning calorimetry (DSC). For pure PEG, the DSC displayed a strong peak at about 58°C;

however, the precipitated sample did not exhibit this peak (Fig. 1.5), indicating that the PEG in the solvent had been thoroughly cleaned.
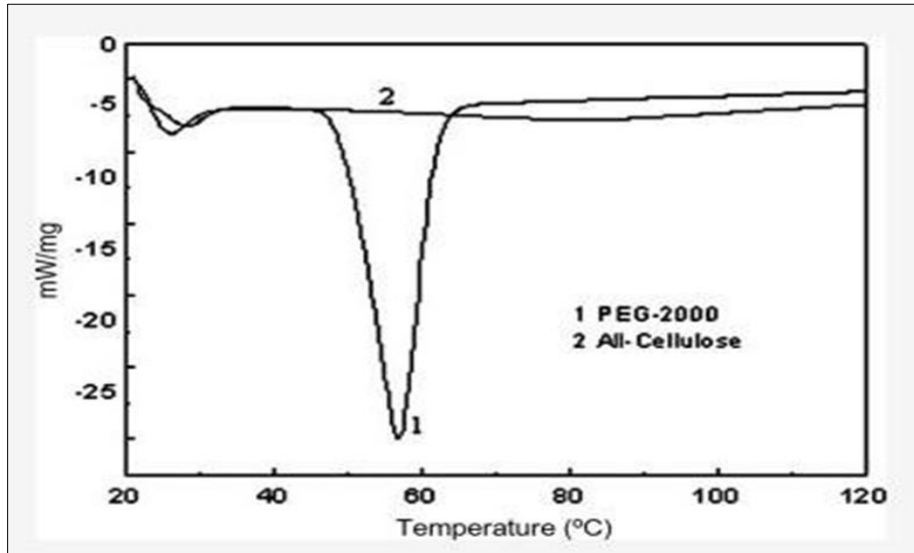

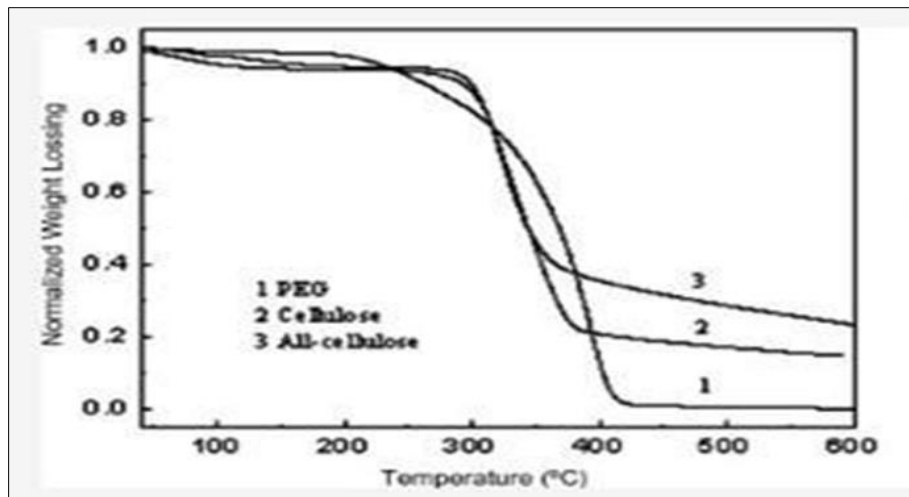**Figure 5** DSC curves of PEG-2000 and all-cellulose composite

Figure 6 TGA curves of cellulose, PEG-2000 and all-cellulose composite

2.7. All-cellulose composites

The creation of green composites, which are characterized by their sustainability, environmental friendliness, and compostability, can be accelerated by fusing cellulose fibers with a "green" matrix. Maya et al. (2007) provided a comprehensive examination of green composites using biodegradable matrices such as poly(lactic acid), poly(butylene succinate), poly(hydroxybutanoate), and soy-based polymers. They concluded that this was a significant obstacle because biodegradable matrices are substantially more costly than conventional ones. Cellulose is another promising matrix material for composites. When the matrix and reinforcement phases are composed of the same polymer, such as cellulose, the products are referred to as self-reinforced polymeric materials (SRPMs) (Kmetty et al., 2010). SRPMs outperform traditional composites and are more economical. All-polymer composites were previously made by impregnating polymer fibers with a polymer matrix that had a lower melting point. A new manufacturing technique for all-polymer composites called "hot compaction" was created by University of Leeds researchers. This method involves melting a portion of the polymer fiber and then recrystallizing it into a matrix that improves the interface and fortifies the fibers.

Nishino et al. (2009) were the first to expand on the success of all-polypropylene composites (Cabrera et al., 2004) by applying this technique to cellulosic materials. They produced all-cellulose composites by dissolving Kraft fibers and using the cellulose solution as a binder matrix for ramie fibers that were aligned uniaxially. These composites' remarkable compatibility improves interfacial adhesion because the reinforcement and matrix are composed of the same material. As a result, these all-cellulose composites had tensile strengths between 480 and 540 MPa. Additionally, cellulose materials can be selectively dissolved to create all-cellulose composites. The matrix is created by dissolving and regenerating a surface layer of cellulose, with the undissolved core serving as reinforcement. Duchemin et al. (2009a) partially dissolved microcrystalline cellulose in LiCl/DMAc and precipitated the dissolved portion to form a matrix around the undissolved core. The cellulose materials for this selective dissolution method can also be pre-formed mats such as filter paper (Nishino and Arimoto, 2007) or regenerated cellulose fibers (Soykeabkaew et al., 2009) using the LiCl/DMAc solvent system. More recently, Han and Yan (2010) employed a PEG/NaOH aqueous solution to dissolve filter paper selectively.

All-cellulose composites are more mechanically sound than other natural fiber-based composites. For instance, Gindl and Keckes (2005) demonstrated that all-cellulose composites derived from MCC exhibit tensile properties that surpass the typical range of randomly oriented biofiber-reinforced polymer composites in terms of elastic modulus (1–13 GPa) and tensile strength (15–140 MPa).

2.8. Cellulose Dissolution

Cellulose is insoluble in water and the majority of organic solvents, although it can dissolve in certain solvents. Complexing agents like cupriethylenediamine (Cuene) and cadmium ethylenediamine (cadoxene) break down the hydrogen bonds in cellulose and facilitate dissolution by forming complexes with its hydroxyl groups. These chemicals are commonly used to dissolve pulp fibers so that capillary viscosity, a measure of cellulose polymerization degree, can be determined. Furthermore, urea dissolves cellulose more easily than strong alkalis like NaOH, which keeps free water in the solution and stops cellulose chains from forming hydrogen bonds. Recent solvent systems for the dissolution of cellulose include N-methylmorpholine N-oxide (NMMO) and lithium chloride/N,N-dimethylacetamide (LiCl/DMAc). Tencel fibers, a type of lyocell fiber, are produced commercially using NMMO. Strong cellulose-solvent interactions and little intrinsic viscosity loss over time make LiCl/DMAc an efficient solvent. An early instance of the use of ionic liquids for this purpose was Graenacher's 1934 discovery that cellulose could be dissolved by combining molten N-ethylpyridinium chloride with bases that contained nitrogen. Ionic liquids were once thought to be impractical, but their potential for dissolving cellulose has since been reassessed. Rogers and his team at the University of Alabama have conducted extensive research on cellulose regeneration and dissolution in ionic liquids. Cellulose can be dissolved without derivation using hydrophilic ionic liquids such as 1-N-butyl-3-methylimidazolium chloride (BMIMCl) and 1-allyl-3-methylimidazolium chloride (AmimCl).

By choosing the right ionic liquid ingredients, it is possible to precisely control the solubility of cellulose in these liquids as well as the characteristics of the final solution. Although it can reach up to 25 weight percent with the use of microwave heating, the dissolution capacity usually falls between 10 and 15 weight percent of the ionic liquid. BMIMCl's high chloride activity and concentration are thought to be very effective at breaking down the complex hydrogen-bonding network in cellulose, which is essential to its dissolution. However, because of competitive hydrogen-bonding with its microfibrils, the water in BMIMCl drastically decreases the solubility of cellulose. It is easy to precipitate cellulose in BMIMCl solution by adding acetone, ethanol, or water.

The regenerated cellulose has nearly the same degree of polymerization and polydispersity as the original, despite having a very different morphology due to the microfibrils fused into a relatively uniform macrostructure. By altering the regeneration procedures, cellulose can be created in a range of structural forms, including powder, tubes, beads, fibers, and films. By altering the degree of crystallinity of the dissolved cellulose during regeneration, amorphous to crystalline cellulose can be produced under different conditions. Additionally, the duration of storage of the cellulose ionic liquid solution affects the microstructure of the regenerated cellulose; a few weeks of room temperature storage can yield amorphous cellulose (Zhu et al. 2006).

Ionic liquids can be recovered and reused following cellulose regeneration, as demonstrated by Zhu et al. (2006). Among the recovery methods are evaporation, ionic exchange, pervaporation, reverse osmosis, and salting out. Pure cellulose is available commercially in a number of forms, each with distinct pharmacological and mechanical properties. The differences in the particles' size, shape, and crystallinity (agglomerated or fibrous) account for these disparities. Microcrystalline cellulose (MCC) is a prevalent and extensively utilized form in the pharmaceutical industry. MCC grades are multifunctional excipients that increase viscosity and thicken liquid dosage forms, bind in wet and dry granulation

processes, improve compressibility, and function as free-flowing agents in solid dosage forms. The mechanical properties of MCC grades are significantly influenced by the size of the particles and the degree of crystallization.

Recent advancements have led to the creation of new MCC grades with enhanced pharmaceutical qualities. Silicated MCC (SMCC) and second-generation MCC grades, sometimes referred to as MCC type II (MCC-II), are two examples. Specialized chemical processes or co-processing with materials like colloidal silicon dioxide are used to make these. Two additional types of pure cellulose are powdered cellulose (PC) and low crystallinity powdered cellulose (LCPC). Regenerated cellulose is another processed form of natural cellulose that is produced by chemically treating it. Initially, cellulose is dissolved in alkali and carbon disulfide to form "viscose." This viscose is converted back to cellulose by passing through a bath of diluted sulfuric acid and sodium sulfate. The cellulose that has been converted is put through further processes to produce the clear film called cellophane.

2.9. Cellulose Ether Derivatives

High molecular weight compounds known as cellulose ethers are created by replacing the hydrogen atoms of hydroxyl groups in cellulose's anhydroglucose units with alkyl or substituted alkyl groups. The molecular weights, chemical structure, degree of substitution, distribution of substituent groups, and molar substitution (if applicable) of cellulose ethers all affect their commercially important characteristics. Solubility, solution viscosity, surface activity, thermoplastic film properties, and resistance to heat, hydrolysis, oxidation, and biodegradation are examples of these attributes. The molecular weights of cellulose ether solutions are directly related to their viscosity. Methyl cellulose (MC), ethyl cellulose (EC), hydroxyethyl cellulose (HEC), hydroxypropyl cellulose (HPC), hydroxypropylmethyl cellulose (HPMC), carboxymethyl cellulose (CMC), and sodium carboxymethyl cellulose (NaCMC) are examples of cellulose ethers that are frequently used.

2.10. Ester Cellulose Derivatives

Cellulose esters, which are mostly water-insoluble polymers, are used extensively in pharmaceutical controlled release formulations, including enteric-coated and osmotic drug delivery systems, because of their good film-forming properties. These polymers are frequently combined with cellulose ethers to create micro-porous delivery membranes. Cellulose esters come in two varieties: inorganic and organic. In the pharmaceutical sector, organic varieties are more significant. Numerous organic cellulose esters, such as cellulose acetate (CA), cellulose acetate phthalate (CAP), cellulose acetate butyrate (CAB), cellulose acetate trimellitate (CAT), and hydroxypropylmethyl cellulose phthalate (HPMCP), are essential for both pharmaceutical research and commercial products. The most popular market formulations using these polymers are enteric-coated dosage forms, which are typically created with acid-resistant polymeric coatings containing phthalate derivatives, particularly cellulose acetate phthalate.

In contrast, cellulose nitrate and cellulose sulfate, which are inorganic cellulose esters, are less significant in medical contexts. Despite being a transparent material with good film-forming qualities, cellulose nitrate, also referred to as pyroxylin, is rarely used alone in pharmaceutical formulations due to its high flammability and poor solubility in common pharmaceutical solvents. The only drug formulation that makes extensive use of it is Collodion, a topical anti-wart solution that is made at a 4% w/v concentration in a diethyl ether/ethanol solvent mixture. Additionally, cellulose nitrate and cellulose acetate blends are used to create micro-porous membrane filters for use in pharmaceuticals.

Drug-containing polymeric films known as bioadhesives and mucoadhesives are made to stick to biological membranes by reacting with mucus or moisture. Since their introduction in the middle of the 1980s, these systems have been acknowledged as successful methods for improving targeted drug delivery on a variety of biological membranes and prolonging residence time (Movassaghian et al., 2011). Because of their thickness and small size, these dosage forms provide better patient compliance than tablets. They may also decrease the frequency of dosing in controlled-release formulations by prolonging residence time at drug absorption sites. These systems facilitate epithelial transport across mucous membranes by improving drug contact with the mucosal barrier, especially for drugs that are poorly absorbed.

Some polymers in these formulations can inhibit proteolytic enzymes in oral formulations of sensitive medications, and others can modulate epithelial permeability by relaxing tight intercellular junctions. Developed for use on the skin and mucous membranes of the gastrointestinal tract, ear, nose, eye, rectum, and vagina, bioadhesives are regarded as cutting-edge drug delivery systems. These formulations' main excipients are film-forming and adhesive polymers, which can be natural, semi-natural, or synthetic macromolecules that stick to mucosal or skin surfaces.

As bioadhesive agents, a variety of polymers—natural, semi-synthetic, and synthetic—have been employed. While acrylic derivatives, carbopols, and polycarbophil are examples of synthetic polymers, natural polymers include things like carrageenan, pectin, acacia, and alginates. Semi-synthetic polymers such as chitosan and cellulose derivatives are

also used in bioadhesive formulations (Deshpande et al., 2009). Bioadhesives frequently contain cellulose derivatives, particularly cellulose ethers. In formulations for transdermal, nasal, vaginal, buccal, and ocular applications, they can be utilized either alone or in conjunction with other polymers. Nonionic cellulose ethers that have been employed in recent advancements include hydroxyethyl cellulose (EC), hydroxypropyl cellulose (HPC), methyl cellulose (MC), carboxymethyl cellulose (CMC), hydroxylpropylmethyl cellulose (HPMC), and anionic ether derivatives such as sodium carboxymethyl cellulose (NaCMC).

Key factors influencing adhesive strength are the target site's pH and the polymer's ability to draw water from mucus. Depending on the specific bioadhesive application, careful selection is necessary because certain bioadhesive polymers, like polyacrylates, have varying adhesion capacities at different pH values. One significant benefit of cellulose ethers, such as NaCMC and HPC, over polyacrylate and thiolated bioadhesive polymers is their reduced reliance on the medium's pH for adhesion time and force. In oral (Deshpande et al., 2009) and transdermal (Sensoy et al., 2009) bioadhesives, cellulose ethers have been investigated either alone or in conjunction with other polymers. Studies have investigated the use of cellulose ethers in combination with other adhesive polymers or polysaccharides to enhance adhesion properties such as adhesion time and force. The literature documents the combined use of polyvinyl pyrrolidone (PVP), hydroxypropyl beta cyclodextrin, polycarbophil, carbopol(s), pectin, dextran, and mannitol with HPMC, HEC, or NaCMC.

Solid dosage forms like tablets, pellets, pills, beads, spherules, granules, and microcapsules are frequently coated for a range of applications. These objectives include protecting sensitive drugs from oxygen and moisture, preventing acidic or enzymatic degradation, masking flavors or odors, and permitting site-specific or time-specific release characteristics. According to Barzegarjalali et al. (2007) and Gafourian et al. (2007), this coating process is necessary for modified release drug delivery systems, such as sustained, delayed, extended, immediate, pulsatile, or step-by-step release forms.

Derivatives of cellulose, both ether and ester, are frequently used to coat solid drugs. Cellulose ethers, which are normally hydrophilic, transform into hydrogels when they come into contact with water. Most celluloses, such as methyl, hydroxypropyl, and hydroxypropylmethyl cellulose, dissolve in water, but some, such as ethyl cellulose, do not. When cellulose ethers absorb water, they can gel, whether they are soluble or insoluble. When the coating polymers in these coated dosage forms come into contact with water, they form hydrogels and gradually dissolve, except the insoluble cellulose ether coatings, which remain as a viscous gel around the tablets. Drug delivery systems that are diffusion-controlled or dissolution-controlled differ in that drug release is caused by the diffusion of drug molecules within this layer.

Conversely, cellulose esters are typically only soluble in specific pH ranges or insoluble in water. Polymers such as cellulose acetate (CA), cellulose acetate phthalate (CAP), and cellulose acetate butyrate (CAB) do not gel in the presence of water. Semi-permeable and pH-sensitive microporous membranes are widely used in their production. These membranes are crucial for pharmaceutical controlled release coatings, particularly in enteric or osmotic drug delivery systems. These polymers are used in the pharmaceutical industry to make a range of cellulosic membrane filters.

Non-petroleum-based energy resources have been expanding as a result of the world's unavoidable depletion of petroleum supplies and the growing emphasis on alternatives worldwide. Since petroleum accounts for 97% of the energy used in transportation, governments and corporations worldwide have spent the last 20 years actively seeking out, creating, and promoting alternative fuel technologies. Ethanol is increasingly being used as vehicle fuel in the United States. Because fermentation can produce expensive ethanol, government subsidies are required to keep costs low. Nearly all ethanol fuel is produced by fermenting sucrose in Brazil or maize glucose in the US, but current technology can be used to produce petroleum ethanol in any other country with a substantial agricultural budget.

The technology for making ethanol from non-food plant resources has advanced significantly over the last 20 years, making it a promising fuel substitute in the near future. Ethanol can be produced from biomass, which includes agricultural by-products like corn stover, waste sugar cane, municipal waste paper, forestry and paper mill residues, cassava and plantain peels, and special energy crops. However, compared to conventional gasoline, the cost of commercializing ethanol through fermentation is still high. The price difference between gasoline and ethanol is getting closer thanks to recent rises in oil prices worldwide. The inevitable carbon loss that occurs during the microbial fermentation of sugars contributes to the price of ethanol.

Although producing ethanol from cane sugar is comparatively simple, problems occur when enzymes are needed to hydrolyze starch into glucose before fermentation, especially when corn or wheat starch is used. Hemicellulose and cellulose, which make up 20–35% and 23–53% of biomass, respectively, contain polymeric sugars that must be released through intensive processing to produce ethanol from biomass. Hemicellulose is a complex chain of arabinose and

xylose that also contains glucose, mannose, and galactose, while cellulose is a polymer of beta-linked glucose units. Acids and enzymes are usually required for the hydrolysis of these carbohydrate polymers; concentrated sulfuric acid is employed for the hydrolysis of biomass carbohydrates. The sugars are hydrolyzed, separated from the acid, and then fermented to produce ethanol.

While reducing sugar degradation during fermentation is essential for the production of ethanol, pre-treatment methods seek to break down the lignin matrix and carbohydrates. The variety of biomass sources, such as hardwood and softwood trees, agricultural waste like corn stover, and non-recyclable paper, makes it difficult to develop an ideal pre-treatment technique. Several pre-treatment techniques that are suited to distinct feedstocks have been investigated by researchers, including steam explosion, hot water, alkaline, solvent, and acid pre-treatments. According to recent comparisons of flow-through and acid-based batch methods, flow-through procedures produce more sugar outputs and cause less sugar degradation, but they also produce more sugar solution.

The purpose of the pre-treatment procedure is to partially hydrolyze carbohydrate polymers and start the breakdown of biomass in order to get them ready for enzymatic conversion. Initially, cellulases were used in a step-by-step procedure (pre-treatment → cellulase hydrolysis → fermentation of ethanol). Since cellulase hydrolysis takes place during glucose fermentation, the simultaneous saccharification and fermentation (SSF) process offers considerable cost savings. Current techniques use a simultaneous saccharification-cofermentation (SSCF) process that ferments all biomass sugars. Although there are difficulties when using biomass as a fermentation substrate, recent acid-based pre-treatments have shown promise in preparing substrates for fermentation.

3. Materials and Method

Agricultural Biomass (Cassava and Plantain Peels) Electronic Weighing Balance (S.Mettler) Laboratory Oven (Hanshin Medical Co, Ltd) Homogenizer(IKA,ultra turax,Japan) Mechanical Shaker (Gallenkamp, England) Laboratory Blender (Hinari Genie) Laboratory Glasswares (Beakers, Conical flasks, Measuring cylinders) Chemical Reagents (Ethanol 90%, Sodium Hydroxide, Hydrogen Peroxide)

3.1. Methodology

3.1.1. Sample Collection and Treatment

Local women in Agbani, Nkanu East Local Government Area, provided the plantain and cassava peels. The plantain peels were gathered from restaurant owners, and the cassava peels were acquired from a processing facility. To get rid of dust and sand, both kinds of peels were cleaned with tap water. They were then divided into pieces, allowed to air dry for seven days, and then baked for three hours at 85 °C. Following cooling, the peels were weighed, ground into a uniform texture, and sieved before being placed in polyethylene bags with labels. Following the procedure of Riantong et al. (2013), which involved alkaline hydrolysis following defatting and deproteination, followed by bleaching, cellulose extraction started within 24 hours of pulverization.

100g of each peel powder was soaked in 1L of 90% ethanol for 16 hours while being shaken intermittently at 150 rpm in order to defatten it. Following three rounds of washing with two liters of distilled water, the mixture was filtered through Whatman filter paper No. 4. For seven hours, the defatted peel powders were dried at 80°C in a hot air oven.

3.1.2. Deproteination of CPP and P

Deproteinization was carried out using the procedures described by Riantong et al. (2013) and Vail (1991). For 24 hours, the defatted CPP and PPP were submerged in a 1 M NaOH solution with a pH of 11.6 and a 1:10 w/v ratio (100g PP/1000ml). A 150rpm mechanical stirrer was used to stir each mixture sporadically. To extract alpha cellulose from each PP, samples were deproteinated, rinsed three times with distilled water, filtered through 11.0 cm filter paper (Whatman No. 4), and then dried in a hot air oven set at 80°C for seven hours.

3.1.3. Cellulose Bleaching

The bleaching procedure followed the guidelines provided by Riantong et al. (2013) and Phongnori (2004). For three hours, CPP and PPP that had been defatted and deproteinated were submerged in a 15% hydrogen peroxide solution. The bleached samples were filtered through 11.0 cm filter paper, rinsed three times with distilled water, and dried for seven hours at 60°C in a hot air oven.

3.1.4. Functional Properties of Cassava Peel Cellulose (CPC) and Plantain Peel Cellulose (PPC)

In addition to settling volume and water and oil retention capacities (Committee on Codex Specifications, 2008), the resulting CPC and PPC were assessed for bulk density, packed density, hydrated density, emulsifying activity, and viscosity (Prakhongpan et al., 2002).

3.1.5. Bulk Density

50g of the sample was put into a graduated cylinder that had been previously weighed, and it was shaken gently. The contents of the cylinder were weighed, and the sample volume was noted. The following formula was used to determine bulk density, which is weight per unit volume (Prakhongpan et al., 2002):

$$Bulk\ density\ (g/ml)\ =\ \frac{\text{Weight of the Sample (g)}}{Volume\ of\ the\ Sample\ (ml)}$$

3.1.6. Packed Density

The sample's predefined weight was contained in a calibrated 10-ml graduated syringe. Until no more volume reduction was possible, manual pressure was applied. According to Prakhongpan et al. (2002), the packed density was calculated by dividing the sample's weight by its minimum volume. The given equation was used to calculate the packed density.

$$Packed\ density\ (g/ml)\ =\ \frac{\text{Weight of the Sample (g)}}{Least\ Volume\ of\ the\ Sample\ (ml)}$$

3.1.7. Hydrated Density

A precisely measured volume of distilled deionized water was placed into a calibrated 10-milliliter graduated cylinder. In order to avoid adhesion to the cylinder walls, a measured weight of the sample was then carefully introduced. The milliliters of water displaced were used to record the volumetric difference between the water before and after the sample was added. According to Prakhongpan et al. (2002), the results were expressed as grams of the sample per milliliter of water displaced. The given equation was used to calculate the hydrated density.

$$Hydrated\ density\ (g/ml)\ =\ \frac{\text{grams of the Sample (g)}}{ml\ of\ the\ water\ displaced}$$

3.1.8. Water Retention Capacity (WRC) and Oil Retention Capacity (ORC)

A glass rod was used to analyze the water retention capacity (WRC) and oil retention capacity (ORC). A 50 ml centrifuge tube containing a 2 g sample and 30 ml of distilled water was used for the WRC evaluation. The mixture was centrifuged at 2000 × g for 15 minutes after being given 10 minutes to settle. The mass of the wet sample precipitate was measured after the supernatant was extracted following centrifugation. Grams of water per gram of sample were used to quantify the WRC outcome. The ORC evaluation adhered to the same procedure as described by the Committee on Codex Specifications (2008), but palm oil was used in place of water. The given equation was used to carry out the WRC and ORC equations.

$$Retention\ capacity\ (g\ water/g\ dried\ sample)\ =\ \frac{\text{grams of the water Water}}{gram\ of\ the\ sample}$$

$$\text{Oil retention capacity (g oil/g dried sample)}\ =\ \frac{\text{grams of oil}}{gram\ of\ the\ sample}$$

3.1.9. Emulsifying Activity (EA)

100 milliliters of distilled water were used to suspend seven grams of the sample, and then 100 milliliters of soybean oil was added. A homomixer (IKA Ultra Turrax-T25, Ika Japan) fitted with the dispersing tool S25N 25F was used to emulsify the mixture. It ran for one minute at 1000 rpm. Four 50 ml centrifuge tubes were filled with the resultant emulsion, and it was centrifuged for five minutes at 1300 × g (Prakhongpan et al., 2002). The given equation was used to calculate the emulsion activity (EA).

$$\text{EA}\ =\ \frac{heightofemulsifiedlayer(cm)\ \times\ 100}{heightofwholelayer\ (cm)}$$

When there was no more water or oil left over after centrifugation, the sample weight was lowered to 1.75 g.

3.1.10. The Hausner's Quotient

This was ascertained by calculating the ratio of each hybrid material quality's packed density (Dp) to bulk density (Db). It is shown by the following formula:

$$H.Q = \frac{Dp}{Db}$$

3.1.11. Settling Volume

To find the settling volume (SV), 1 g of the cellulose and dietary fiber samples were first combined with 70 ml of distilled water in a 100 ml screw-cap bottle. The samples were ultrasonically treated for 30 minutes to ensure water saturation and eliminate excess gas. The mixtures were then degassed using vacuum suction for 30 minutes and stored in a cold environment for 24 hours to enhance water penetration into the sample interstices. Each mixture was then quantitatively transferred to a 100 ml volumetric cylinder, and distilled water was added to bring the volume down to 100 ml. The volume of the sample residue layer, or SV, was visually evaluated after 24 hours at room temperature, per Prakhongpan et al. (2002).

4. Results

Table 1 % Crude fat and Protein Composition of CPP and PPP

S/N	Chemical composition	CPP	PPP
1	Crude fat	3.20%	2.18%
2	Protein	4.50%	3.85%

Table 2 Functional Properties of the CPC and PPC compared with the CC

S/N	Functional property	CPC	PPC	CC
1	Bulk density (g/ml)	0.52	0.55	0.21
2	Packed density (g/ml)	0.68	0.73	0.28
3	Hydrated density (g/ml)	2.78	2.69	1.80
4	Emulsifying activity	41.05	40.90	55.95
5	WRC (g water/g dried sample)	3.09	2.96	1.98
6	ORC (g oil/g dried sample)	0.11	0.09	3.23
7	Setting volumes (ml/g)3	15.20	15.19	14.04
8	Hausner's Quotient	1.31	1.33	1.33

5. Discussion

Wastes derived from agricultural products are known as agricultural biomasses. Most commonly, biomass refers to plants or plant-based materials—specifically, lignocellulose biomass—that are not utilized for food or feed. In addition to improving waste materials' value, recycling agricultural biomass into raw materials for industries will address the implications for public health. The production of cellulose from plantain and cassava peels, two types of agricultural biomass, was highlighted in this study. Following defatting and deproteinization, cellulose was extracted from the peel powder in this study using alkaline hydrolysis. Commercially available cellulose and cellulose made from plantain and cassava peels were compared in terms of their physicochemical characteristics. Cassava peel powder (CPP) and plantain peel powder (PPP) have crude fat contents of 3.20% and 2.18%, respectively, and protein contents of 4.50% and 3.85%, respectively. This is in good agreement with the work of Okorie et al. (2015).

The method for removing fat from the peels (CP and PP) was polarity. A dipolar substance, fat has both hydrophilic and hydrophobic qualities. According to science, "like dissolves like," meaning that fat, a polar solvent, will dissolve in ethanol, a polar solvent. Slightly polar alcohol dissolves fats because the dipole-dipole force that attracts polar molecules is insoluble in non-polar solvents. This aligns with the research conducted by Intranupakorn (2007).

Deproteinization was accomplished at a pH of 11.6 after 24 hours. In line with Riantong et al. (2013), this total. According to earlier research, deproteinization was successful at pH values between 11.2 and 12.0 (Prakhonpan et al., 2002, Phongori, 2004, Intarasil and Sringam, 2006). As reported by other independent workers (Prakhonpan et al., 2002, Phongori, 2004, Intarasil and Sringam, 2006), the deproteination pH of 11.6 in this study was within that range.

The oxidizing property of hydrogen peroxide (H2O2) led to the bleaching mechanism of H2O2 in the CPP and PPP. According to Riantong et al. (2013), effective bleaching was accomplished after three hours at a 15% H2O2 concentration. A powerful oxidizing agent, H2O2 is used to remove pigment from a variety of organic compounds. H2O2 separates into a perhydroxyl anion in an alkaline environment, which then combines with bleach activator to produce peracid. According to Abdul-Halim and Al-Deyab (2013), peracid is a more effective bleaching agent than H2O2 and can be used for bleaching in mild room temperature conditions in a shorter amount of time. Physical characteristics that show flow ability and, consequently, aggregate behavior of powdered samples are packed and bulk densities. Food-grade and pharmaceutical-grade cellulose will aggregate well, making it suitable for use as bulking agents. According to Sreerama et al. (2009), bulk density is a good indicator of structural changes and is defined as the weight of fiber per unit volume, frequently expressed as g ml-1.

An indicator of a powder or granular material's flow ability is the Hausner's ratio. A greater range of industries use it (Garcia et al., 2007). A Hausner's ratio above 1.25 is regarded as a sign of inadequate flow capability. The three cellulose products—commercial cellulose (CC), plantain peel cellulose (PPC), and cassava peel cellulose (CPC)—have Hausner's quotients of 1.31, 1.33, and 1.33, respectively, which are nearly identical. These indicate the likelihood that cellulose made from agricultural biomass of interest will have the same functional characteristics as cellulose sold commercially, making them suitable options for cellulose-using pharmaceutical and food raw materials.

Table 2 shows the bulk, packed, and hydrated densities of commercial cellulose (CC), plantain peel cellulose (PPC), and cassava peel cellulose (CPC). Because of the CC's potentially smaller particle size, the CPC and PPC values are higher than the CC's. Sieve analysis was not used to determine the cellulose's particle sizes. These findings concurred with Prakhonpan et al. (2002)'s research. Compared to CC (1.98), the water retention capacity (WRC) of the CPC (3.09) and PPC (2.96), respectively, is higher. Naturally, fiber or cellulose has an ability to absorb water due to the large number of hydroxyl groups forming a hydrogen bond with water.

In addition to food applications, the properties of fiber in imbibing and swelling in water are crucial for human gastrointestinal function and the outcomes of the analysis. The properties of cellulose are indicated by its water retention capacity (WRC) and oil retention capacity (ORC). Depending on the type of raw material, cellulose's WRC and ORC may have varying capacities. High WRC cellulose is appropriate for goods like baked goods that require volume expansion and texture enhancement.

In comparison to the CPC (0.11) and PPC (0.09), the CC displayed a higher ORC (3.23). Products in the food and pharmaceutical industries that need to improve their texture can benefit from cellulose with a high ORC. There is a notable difference between the ORC values of the cellulose produced in this study and commercially prepared cellulose, which suggests that the latter may not be the best option for applications requiring a high oil retention capacity. Since the CC had a higher ORC than the CPC and PPC, it was expected that it would exhibit a higher emulsifying activity (55.95) than those of the CPC (41.05) and PPC (40.90). Thus, even though they have a lower capacity to emulsify, the celluloses derived from agricultural biomass are always excellent choices for emulsifying agents in food, cosmetics and pharmaceutical products.

6. Conclusion

One of the biggest issues facing agro-based industries in developing nations is waste management. Nigerian agricultural biomasses are primarily burned outdoors, which has negative environmental effects (Babayemi et al, 2009). Pollution of the air and water is one of the major health risks associated with improper solid waste disposal. In addition to causing public annoyance and impeding community and life development, this increases the prevalence of rodent and insect diseases. Natural resources are needlessly depleted when such materials are not economically salvaged and repurposed. Recycling these wastes into industry-useable raw materials will reduce pollution in the environment and encourage life

science entrepreneurs. The physicochemical characteristics of cellulose were produced in this study by processing the peels of plantains and cassava close to those of commercially sold cellulose.

Recommendation

Appropriate government agencies and private industry sectors should start raising public awareness of the advantages of using agricultural biomass. The process of turning plantain and cassava peels into industrial raw materials like cellulose will reduce the environmental harm caused by these wastes, unavoidably increasing crop value, giving farmers more financial leverage, and creating jobs for life science graduates.

Compliance with ethical standards

Disclosure of Conflict of Interest

The authors declare that they have no known financial or personal conflicts of interest that could have appeared to influence the work reported in this paper.

References

[1] Adebayo, A.O. (2008) Using cassava waste to raise goats. Project 2008-4345. *World Bank Development Marketplace*; 2008; 2008-4345.

[2] Adesanya, O.A., Oluyemi, K.A., Josiah,S.J., Adesanya, R.A., Shittu, L.A.J., Ofusori, D., Bankole, N, Babalola G.(2017). Ethanol production by *saccharomyces cerevisiae* from *(Digitaria exilis)* and soybeans *(Glycine max)* and sensory properties of noodles produced from the flour. Asian *Journal of Advances in Agricultural Research*.1(2):1-13.

[3] Adepoju, O.T., Adekola, Y.G., Mustapha, S.O., Ogunlola, S.I.(2010). Effects of processing methods on nutrients retention and contribution of cassava *(Manihot spp)* to nutrient intake of Nigerian consumers. *African Journal Food AgricultureNutrition and Development*; 10:20992111.

[4] Akpabio, U.D., Akpakpan, A.E., Udo I.E., Nwokocha, G.C. (2012). Comparative study on the physicochemical properties of two varieties of cassava peels *(Manihot utillissima Phol).International Journal of Environment and Bioenergy*; 2(1):19-32.

[5] Apata, D.F., Babalola, T.O.(2012). The use of cassava, sweet potato and cocoyam, and their byproducts by non-ruminants. *International journal of food science and nutrition engineering*. 2(4):54-62.

[6] Aro, S.O., Aletor, V.A., Tewe, O.O., Agbede, J.O. (2010). Nutritional potentials of cassava tuber: A case study of a cassava starch processing factory in south-western Nigeria. *Livestock Resource Rural Development*;22(11).

[7] Avcıoğlu, A., Dayıoğlu, M., & Türker, U. (2019). Assessment of the energy potential of agricultural biomass residues in Turkey. *Renewable Energy*, *138*, 610–619. https://doi.org/10.1016/j.renene.2019.01.053

[8] Babayemi, O.J., Khadijah, T.D., Abideen, A.A.K., Davies, O.N, *et al.* (2009). Determination of potash alkali and metal Contents of ashes obtained from peels of some varieties of Nigeria grown *Musa species. Bioresources*5: 1384-1392.

[9] Choong., Ferdinand, X., Back, Marcus., Steiner., Svava, E., Melican, Keira., Nilsson, K., Peter, R., Edlund, Ulrica., Richter-Dahlfors., Agneta (2016). Non-destructive, real-time determination and visualization of cellulose, hemicelluloses and lignin by luminescent *oligothiophenes''. Scientific Reports.*6:35578.

[10] Christopher, I.N., Onyekwe, C.E., Justus, I.O., Nkwoada, A. (2016). The proximate analysis and biochemical composition of the waste peels of three cassava cultivars. *International Journal of Scientific Engineering and Applied Science (IJSEAS)* ;(2)11.

[11] Dauenhauer, Paul., Krumm, Christopher., Pfaendtner, Jim. (2016). ''Millisecond Pulsed Films Unify the Mechanisms of Cellulose GFragmentation''. *Chemistry of Materials.* 28(1):0001.

[12] Edgar, K.J. (2007). Cellulose Esters in Drug Delivery. *Cellulose* ; 14(1): 49-64.

[13] Elly Sabiiti. (2011) Utilising agricultural waste to enhance food security and conserve the environment. *African Journal of Food, Agriculture, Nutrition and Development*11(6).

[14] Ekwe ,O.O., Nweze, B.O., Uchewa, E.N.(2011). Effects of sun-dried cassava peels supplementation on the performance of weaner pigs. *Asian Journal of Applied Sciences*; 4:794-800.

[15] Emaga, T.H., Andrianaivo, R.H., Wathelet, B., Tchango, J.T., Paquot M. (2007). Effect of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Journal of Food Chemistry*;103:590-600.

[16] Emaga, T.H., Robert, C., Ronkart, S.N., Wathelet, B., Paquot, M. (2008). Dietary fibre components and pectin chemical features of peels during ripening in banana and plantain varieties. *Biosresource Technology*;99:4346-4354.

[17] Emaga, T.H., Bindelle, J., Agneesens, R., Buldgen, A., Wathelet, B., Paquot M. Ripening influences banana and plantain peels composition and energy content. (2011). *Tropical Animal Health Production.*43:171-177.

[18] Emaga, T.H., Robert, C., Ronkart, S.N., Wathelet, B., Paquot M. (2008). Dietary fibre components and pectin chemical features of peels during ripening in banana and plantain varieties. *Biosresource Technology*. 99:4346-4354.

[19] Emaga, T.H., Bindelle, J., Agneesens, R., Buldgen, A., Wathelet, B., Paquot M. (2011) Ripening influences banana and plantain peels composition and energy content. *Tropical Animal Health Production.*43:171-177.

[20] Eun-Hye, I., Hye-Jung, Y., Mi-Sun, H., Dong-Ho, B. (2010). Development of banana peel jelly and its antioxidant and textural properties. *Food Sci Biotechnology.*19: 449-455.

[21] Happi-Emaga, T., Bindelle, J., Agneesens R., Buldgen, A., Wathelet, B., Paquot M. (2011) Ripening influences banana and plantain peels composition and energy content. *Tropical Animal Health Production*. 43:171-177.

[22] Happi-Emaga T., Robert, C., Ronkart, S.N., Wathelet, B., and Paquot M.(2008). Dietary fibre components and pectin chemical features of peels during ripening in banana and plantain varieties. *Biosresource Technology*. 2008;99:4346-4354.

[23] Happi-Emaga T., Herinavalona-Adrianaivo, R., Wathelet, B, Tchango- Tchango, J., & Paquot M. (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry*, 103:590-600.

[24] Happi, E.T., Adrianaivo, R.H., Wathelet, B., Tchango, T.J., Paquot M. (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Journal ofFood Chemistry*, 103, 590-600.

[25] Idugboe, O.D., Nwokoro, S.O., Imasuen, A. (2015). Chemical composition of cassava peels collated from four locations (Koko, Warri, Okada and Benin City), brewers spent yeast and three grades of ''caspeyeast''. *International Journal of Science and Research.*78:96

[26] Jiang, J.K., Sands, J.R. (2015). Odour and Ammonia Emission from Broiler Farms. Australia: *A Report for the Rural Industries Research and Development Corporation*. Available online:http://www.rirdc.gov.au/publications.

[27] Jideofor, I.M. (2015). Chemical adjustment of effluent from cassava processing plant prior to safe disposal.*Nigerian Journal of Technology (NIJOTECH*);34(4):883-885.

[28] Kuda, Dewage., Supun, Charuni., Nilanaeka, Rajapasha., Madme., Dulan, Somendrika., Indira Wickramasinghe. (2017). Nutritional and toxicological composition analysis of selected cassava processed products. *Potravinarstvo Slovak Journal of Food Sciences*; 11(1).

[29] Klem, Dieter., Heublein, Brigitte., Fink, Hans-Peter., Bohn, Andreas (2005). ''Cellulose: Fascinating Biopolymer and Sustainable Raw Material''. *Angew. Chem. int. Ed*. 44(22):3358-93

[30] Oladele, E., Khokhar, S. (2011). Effect of domestic cooking on the polyphenolie content and antioxidant capacity of plantain (*Musa paradisiaca*). *World Journal of Dairy & Food Sciences*. 6: 189-194.

[31] Ooye, D.A., Oso, G.K., Olalumade, B.B. (2014). Effects of different processing methods on the proximate and cynogenic composition of flour from different cassava cultivar. *Journal of Agriculture and Allied Sciences*; 2319-9857.

[32] Olufunke, O.E., Ogugua, C.A., Hans, P.B., Thaddeus, C.E.(2010). Protein enrichment of cassava pee by submerged fermentation with Trichoderma viride (ATCC 36316). *African Journal of Biotechnology*. 9(2):187-194

[33] Papathanasopoulos, A., Camilleri, M. (2012). Dietary fibre supplements:effects in obesity and metabolic syndrome and relationship to gastrointestinal functions.

[34] Perez-Jimenez, J., Serrano, J., Tabernero M., Arranz, S., Diaz-Rubio, M.E., Garcia-Diz, L., Goni

[35] ,I., Saura-Calixto, F. (2009). Bioavailablity of phenolic antioxidants associated with dietary fibre: plasma antioxidant capacity after acute and long-term intake in humans. Plant Food Human Nutrition; 64(2):102-107.

[36] Peng, B.L., Dhar, N., Liu, H.L and Tam, K.C. (2011). ''Chemistry and applications of nanocrystalline cellulose and its derivatives: A nanotechnology perspective'' (pdf). The *Canadian Journal of Chemical Engineering*.89 (5):1191-1206.

[37] Phirom-On, K., & Apiraksakorn, J. (2021). Development of cellulose-based prebiotic fiber from banana peel by enzymatic hydrolysis. *Food Bioscience*, *41*, 101083. https://doi.org/10.1016/j.fbio.2021.101083

[38] Pranger, L., Tannenbaum, R. (2008). ''Biobased Nanocomposites Prepared by in Situ Polymerization of *Furfuryl* Alcohol with Cellulose Whiskers or Montmorillonite Clay''. Macromolecules. 41(22):8682-8687.

[39] Romeo., Tony (2008). Bacterial bioflims. Berlin:Pp.258-263.

[40] Romeo Lopaz, M.R., Osorio-Diaz, P., Bello-Perez, L. A., Tovar, J., and Bernardino-Nicanor, A. (2011). Fiber concentrate from organe (*Citrus sinensis Ligase)* bagase: Charaterization and application asbakery product ingredient.

[41] Sarkiyayi, S.S., Agar, T.M.(2010). Comparative analysis on the nutritional and antinutritional contents of the sweet and bitter cassava varieties. *Advanced Journal ofFood Science Technology*; 2(6):328-334.

[42] Somendrika, M.A.D., Wickramasinghe, I., Wansapala, M.A.J., Peiris, S.(2017). Nutritional composition of cassava cultivar ''CARI555''. *Pakistan Journal of Nutrition*; 16:216-220.

[43] Tchobanoglous, G., Theisen, H., and Vigil, S. (1993). Integrated solid waste management. In A.G techobanoglous (Ed.), *Engineering principles and management issues.* Pp.3-22.

[44] Thoorens, G., Krier, F., Leclercq, B., Carlin, B., Evrard, B. (2014). ''Microcrystalline cellulose, a direct compression binder in a quality by design environment—a review''. *International Journal of Pharmaceutics*. 473(1-2):64-72.

[45] Ubwa, S.T., Otache, M.A., Igbum, G.O., Shambe, T. (2015). Determination of cyanide content in three sweet cassava cultivars in three local government areas of Benue State, Nigeria. *Food and Nutrition Sciences*; 6:10781085.

[46] Vitali, D., Dragojevic, I.V., Sebecic, B. (2009). Effects of incorporation of integral raw materials and dietary fibre on the selected nutritional properties of biscuits. *Journal of Food Chemistry*; 114:1462-1469.

[47] Wheatley, C., Chuzel, G., Cassava. (2008). the nature of the tuber and the use as a raw cassava peel hydrolysate. *The Internet Journal of Microbiology*; 5:1-5.

[48] Wang, Hui., Gurau, Gabriela., Rogers, Robin D. (2012). ''Ionic liquid processing of cellulose''.

[49] Chemical Society Reviews. 41(4):15-37.

[50] Vitali, D., Dragojevic, I.V., Sebecic B. (2009). Effects of incorporation of integral raw materials and dietary fibre on the selected nutritional properties of biscuits. *Journal of Food Chemistry*; 114:1462-1469.

[51] Zucco,F., Borsuk. Y., Arntfield, S.D (2011). Physical and nutritional evaluation of wheat cookies supplemented with pulse flours of different particle sizes. *Food Science Technology*44:2070-2076.