Chapter 3

Biomaterial from Oil Palm Waste: Properties, Characterization and Applications

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Abstract

Oil palm are among the best known and most extensively cultivated plant families, especially Indonesia and Malaysia. Many common products and foods are derived from oil palm, its making them one of the most economically important plants. On the other hand, declining supply of raw materials from natural resources has motivated researchers to find alternatives to produce new materials from sustainable resources like oil palm. Oil palm waste is possibly an ideal source for cellulose-based natural fibers and particles. Generally, oil palm waste such as oil palm empty fruit bunches, oil palm trunk, oil palm shell and oil palm ash are good source of biomaterials. Lack of sufficient documentation of existing scientific information about the utilization of oil palm waste raw materials for biomaterial production is the driving force behind the this chapter. Incorporation of various types of biomaterial derived from oil palm waste resources as reinforcement in polymer matrices lead to the development of biocomposites products and this can be used in wide range of potential applications. Properties and characterization of biomaterial from oil palm waste will not only help to promote further study on nanomaterials derived from non-wood materials but also emphasize the importance of commercially exploit oil palm waste for sustainable products.

Keywords: waste as green potential, cellulose fiber, oil palm particle, nanocellulose, biocomposites

1. Introduction

Sensitivity and concern for ecology and technology have sparked a new tendency towards the use of environmentally friendly materials in the world. Environmental-friendly "waste to wealth" programs are becoming increasingly important as a step to exploit and use biomass materials as raw material for biocomposite products for added value and new products. Biomass fibers (natural fibers, agricultural waste fibers, industrial timber waste etc.) have many techno-economic advantages over synthetic fibers such as glass fibers, carbon fiber and so on. Even in 1938, history has shown how Henry Ford uses soybean residues as a major raw material for the production of car interior frames components.

In general, there is continuous attempts to produce more high-value products from biomass. For example, biomass fibers from palm oil (OPBF) can be found continuously from oil palm fractures during pruning activities, when processing from oil palm stems during replanting (after 25 years) and periodic processing. Until this day, palm oil processing activities yield only 10% palm oil and palm kernel oil while the remaining 90% remain in the form of biomass or waste is still not used for the industry.

The oil palm industry has been producing a lot of oil palm biomass wastes in field and oil palm mills. The waste from mill consist of pressed fruit fibers (PFF), empty fruit bunch (EFB), oil palm shell (OPS), palm oil mill effluent (POME), whilst the other wastes from the plantation comprises of oil palm trunks (OPT) and oil palm fronds (OPF) during replanting after achieving its economic life spans [1]. The increase in oil palm plantation has been producing the waste in large quantities during the replanting; especially oil palm fronds (OPF) and oil palm trunk (OPT). Generally, 24% of OPF obtained from each oil palm trees in a year during harvesting at fresh fruit bunches (FFB) in the field. Meanwhile, OPT accounted for 70% of the replanting activities [2]. This means the potentiality of OPT availability would increase continuously as plantation is increasing and replanting is done throughout the year. Along with these two wastes, there are also other wastes like empty fruit bunch (EFB), oil palm shell (OPS) and waste (effluent) palm oil mill effluent (POME) [3].

These renewable biomass sources can be used for the development of biocomposites, power generation, paper production, construction board fillers, solid wood, mulching and soil conditioning as well as many other uses. Availability, price, performance, and biodegradable nature are among the factors that act as catalysts to promote the use of lignocellulose fiber of oil palm wastes as a value-added product. The oil palm sector generates a large number of biomass categorized as agricultural wastes which up to now only 10% are used as alternative raw materials for biocomposite-based industries, industrial raw materials, fertilizers, animal feeds, chemical derivatives and others. Much of this residual waste is not used but contributes to severe environmental problems when left in processing factories and farms just like that. Previous research on biomass and other agricultural waste has shown potential in its use for the production of various types of value-added products such as medium-density panel, chip board, thermoset composite and thermoplastic, nano biocomposite, pulp and paper manufacture [4, 5].

Through intensive research and development attempts, the world's oil palm biomass has been commercialized in a variety of biomass-based products. The use of lignocellulosic material from oil palm biomass for various types of value-added products through chemical processing, physical and biological innovation is now evolving.

2. Oil palm waste as green potential

Palm oil is one commodity which demand is growing very rapidly in world and provide an important contribution to economic development. Increased demand for palm oil in the form of vegetable oils encourage the countries to spur the development of oil palm plantations. Consequently, with the increasing development of the palm oil industry will cause the increase in palm oil mill effluents.

Despite this enormous production, the oil consists of only a minor fraction of the total biomass produced in the plantation. The remainder consists of a huge amount of lignocellulosic materials in the form of fronds (OPF), trunk (OPT), empty fruit bunches (EFB), pressed fruit fiber (PFF), pruning oil palm frond (POPF), and oil palm ash (OPA). Fortunately, all of the wastes are categorized as organic wastes that are environmentally degradable. However, owing to the large quantities generated, these wastes have the potential to pollute the environment. Sumanthi et al. [6] reported that the amount of biomass produced by an oil palm tree, include oil and lignocellulosic materials, is 231.5 kg dry weight/year.

Globally, oil palm biomass is produced and utilized in million metric tonnes annually. With the anticipated higher fresh fruit bunch yields and increase in planted areas in the world expected to produce more than 295 million tonnes of wastes annually. In Malaysia, the oil palm waste are produced of 135 million tonnes annually [7]. Meanwhile, Indonesia produced 143 million tonnes of the oil palm biomass annually [8, 9].

Solid wastes of EFB and OPT has higher potential for commercial exploitation than the other types of biomass waste [8]. Consequently, EFB and OPT, which collectively comprise the bulk of lignocellulosic waste are available for commercial exploitation. However, producer countries of oil palm in the world such Malaysia and Indonesia, the zero-waste strategy must applicated to maintain the competitive edge of oil palm industry [9]. Other potential biomass wastes were OPF from the plantation fields. Fronds are obtained during regular pruning on FFB harvesting, when trees exceeding the economical age are felled [10].

An oil palm tree reaches an average volume of 1.638 m^3 after its commercial life span [11]; therefore, more than 20 and 18.5 million m^3 of biomass from OPT are available annually in Malaysia and Indonesia, respectively. Bakar et al. [11] also reported that, the high OPT that can be used only 2/3 parts and recovery of oil palm lumber (outer part) generated an average of several patterns is tested is 30% [11], it can be generated about 5 million m^3.

The oil palm wastes can be utilized to produce various types value added products which mean the resources of the substitute's material on wood-based industry. Many studies have investigated the utilization of solid oil palm wastes, utilization of EFB as alternative of fertilizer using EFB waste and liquid waste of oil palm factory as filler in biocomposites have been done for particleboard or fiberboard using cement as adhesive or thermosetting adhesive such as an urea formaldehyde have been conducted [3]. EFB can also be used as a major component of specialized construction materials [12, 13]. Previous studies and the latest on oil palm biomass waste have shown the potentiality in its use for the production of various types of value-added products such as medium density panels, block board, laminated veneer lumber (LVL), mineral-bonded particleboard, plywood, chipboard, thermoset and thermoplastic composites, nanobiocomposite, pulp and paper manufacturing [14]. Islam et al. [15] used OPS as activated carbon. Abdul Khalil et al. [16] investigated the conversion of OPT and oil palm EFB into new plywood. Other researchers such as Zaidon et al. [17] and Deraman et al. [18] worked on making particleboard by mixing EFB and rubber wood. Oil palm biomass wastes in field and oil palm mills is illustrated in **Figure 1**.

The motivation for using OPT as plywood was initially due to the difficulty in obtaining good quality timber, as well as the abundance of OPT in developing countries like Malaysia and Indonesia [3]. However, oil palm-based plywood mills only utilize about 40% of the OPT and the other 60% is discarded as waste due to its insufficient properties [19]. Only the outer part of OPT can be used for plywood, while the inner part of OPT, which is not strong enough to use as lumber, is discarded in large amounts. It is highly susceptible to degradation agents due to its high moisture content (around 80%) [19]. Abdul Khalil et al. [16] investigated the development of hybrid plywood by utilizing OPT and oil palm EFB. The results showed that hybridization of EFB with OPT improves some of the properties like bending strength, screw withdrawal, and shear strength of the plywood.

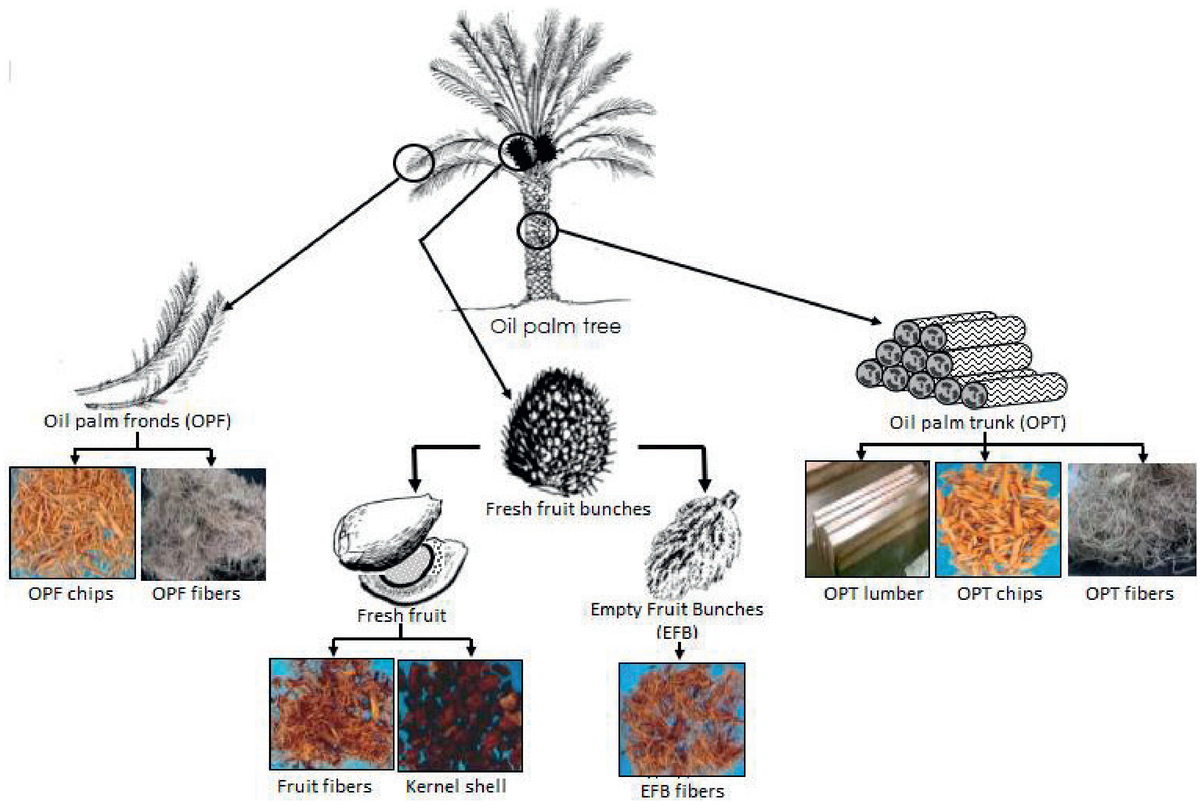

Figure 1. Various oil palm waste form and its derivative.

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3. Properties and characterization of various oil palm waste and their products

3.1. Structure and morphology of oil palm tree

The cell wall structure of oil palm fibers consists of primary layer (P) and secondary layer (S1, S2 and S3). In general, oil palm fibers have varied variations in size, shape and structure of cell walls. Almost all the fiber structures are round. The layers of S1, S2 and S3 are strongly bonded and form structures such as sandwiches where microfibrils S1 and S3 corners are parallel to S2 layers. This sandwich structure provides additional strength to fiber for resistance to water strain, curve resistance to compressive strength, and bending stiffness to bending force. The primary walls of all oil palm fibers look like a thin layer. Some primary walls are clearly distinguishable between the middle lamella to each other.

Studies show that the S2 layer is the majority layer of cell wall. This layer affects the strength of a single fiber. OPT fibers are found to have the most thick S2 layers of 3.43 μm. According to the S2 layer thickness, the OPT is estimated to have the highest strength as the fiber strength is dependent on the cellulose microfibrils that are in line with the fiber axis of the S2 layer [13, 20, 21].

3.2. Properties of various oil palm wastes

EFB fibers are hard and strong multicellular fibers that have a central part called lacuna. Its porous surface morphology is important to provide better mechanical links with matrix resin for composite fabrication [22]. The fiber cross section is a polygon with a bundle or a vascular packet that is compact and surrounded by thickened layers of cells. Vascular fibers in monocytes are usually surrounded by several layers of thick cell walls that serve to provide tensile strength to side compression power [23]. OPF fibers consist of various sizes of vascular bundles. Vascular files are widely found in thin-walled parenchyma tissues. Each bundle consists of round gloves, vessels, fibers, phloem, and parenchyma tissue. The xylem and phloem tissues are clearly distinguishable where the phloem is divided into two separate parts in each bundle [12].

Different chemical compositions according to plant species and parts in the plant itself. It also varies by location, geographical condition, age, climate and soil conditions [24]. **Table 1** shows the differences in chemical composition between various types of oil palm biomass waste.

In order for many applications, oil palm solid waste has physical and mechanical properties. **Table 2** shows the properties include physical and mechanical of different part of oil palm solid waste. These properties are very important in reinforcement of biomass in polymer composites. Dungani et al. [34] investigated that physical, mechanical and chemical properties of various oil palm waste were examined to assess for many applications.

Fibers	Extractive (%)	Holocellulose (%)	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)
EFB	2–4	68–86	43–65	17–33	13–37	1–6
OPF	2–5	80–83	40–50	34–38	20–21	2–3
OPT	4–7	42–45	29–37	12–17	18–23	2–3
OPS	0.9–2	40–47	27–35	15–19	48–55	1–4

Sources: [25–29].

Table 1. Chemical composition of oil palm biomass waste.

Properties	EFB	EFB	EFB	OPT
Density (gr/cm^3)	0.7–1.55	—	—	1.1
Tensile strength (MPa)	0.1–0.4	71	51.73–82.40	300–600
Young modulus (GPa)	1–9	1.7	0.95–1.86	15–32
Elongation et break (%)	8–18	11	9.5–12.15	—

Sources: [30–33].

Table 2. Physical and mechanical properties oil palm solid waste.

3.3. Isolation and characterization of cellulose fibers from oil palm waste

Many researcher investigated the isolation and characterization cellulose fibers from oil palm waste. They studied about isolation of cellulose from many part of oil palm waste, which are chemical treatment and mechanical treatment. There are several ways to isolate cellulose from oil palm solid waste, such as homogenization, ultrasonication, electrospinning, acid hydrolysis, and steam explosion [33]. The main purpose of extracting cellulose is to remove existing non-cellulose components such as hemicellulose, lignin, extractive compounds to obtain cellulosic nano fiber [35].

The following are the results of several researchers who conducted their research on oil palm solid waste. Nasution et al. [36] report their research has isolated cellulose from EFB with hydrochloric acid. The result show that the microcrystalline cellulose (MCC) was found in the form of alpha cellulose. From SEM analysis this treatment affected the structural of morphological of resulting of microfibrillated cellulose. Chieng et al. [37] investigated extraction nanocellulose from OPMF by acid hydrolysis. They used sulfuric acid to remove amorphous region of cellulose to found nanocellulose crystalline. The result show that increased crystallinity of cellulose after removing hemicellulose and lignin. After analysis process the fiber surface to be smoother and reduction in diameter and size. The diameter of nanocellulose about 1–6 nm and rod-like shape.

Nordin et al. [38] also isolated cellulose with sulfuric acid from OPF. The result show that nanocrystalline cellulose improved. From TEM analysis showed good dispersion of individual fiber resulted from chemo-mechanical treatment. They were subjected that the nanocellulose derived from OPF is suitable for many application such as tissue engineering, medical implants, drug delivery, wound dressing and cardiac devices due to their excellent properties. Nazir et al. [39] produced cellulose from EFB with formic acid and hydrogen peroxide. Owolabi et al. [40] studied isolation of cellulose from OPF rachis vascular bundle using sodium hydroxide and hydrogen peroxide.

Shanmugarajah et al. [41] studied isolation of nanocellulose from EFB and investigated with sulfuric acid. Indarti et al. [42] produced cellulose nanocrystal from EFB by TEMPO mediated process follow with ultrasonication. They studied the effect of drying and solvent exchange process on thermal stability.

3.4. Production and characterization of particles from oil palm waste

Several methods has been implied by researcher to produce nanoparticle such as mechanical process, supercritical fluid extraction and solvent extraction [43]. These methods are intended for removing the residual impurities from sources including mechanical pressing. Nanoparticles as one form of nanomaterials like nanotubes and nanolayer, depend on the numbers of dimensions in nano range. Nano particles are small size, narrow size distribution, high dispersion tendency and lower aggregation form [44]. Producing nanomaterials could be preparing by different methods, such as mechanical treatments, chemical treatments, electrospinning method and so on.

Abdul Khalil et al. [43] investigated that OPS as nanoparticles for reinforcement in polymer composites. In prepared the nanoparticles, they used solvent extraction method. From analysis, the shape and surface of defatted OPS particles were angular, crushed shapes and irregular. Liauw et al. [45] stated that the bioresources when used extraction with supercritical fluid, the high purity of oil could produced.

Many researchers also concerned to produce oil palm nanoparticles in the form of activated carbon and oil palm ash. Ruiz et al. [46] produced and characterized the activated carbon particle from OPS. Sukiran et al. [47] studied biochar particles from EFB by pyrolysis process by using fluidized bed reactor. Biochar particles can be used as fuel in form of briquettes, reinforcement in polymer composites, as antifouling in polymer membranes, biocatalyst and ink. Abdul Khalil et al. [48] investigated nanoparticles from oil palm ash (OPA) which is rich siliceous material. They successful reduce the size with ball mill process for 30 hours. Saba et al. [44] investigated nanoparticles from EFB with physical treatment and chemical treatment. To reduce macromolecular size to nano-size used high energy ball mill. Nasir et al. [49] succeeded to produce reduced rapheme oxide from rapheme oxide using OPL, PKS and EFB.

4. Potential application of oil palm waste-based composites

Over the past few decades, the polymer science have been development in a wide spectrum since emergence natural fiber-reinforced polymer composite materials. Its natural fiber composites have used in various applications such as automotive components, package trays, door panels, headliners, dashboards and interior parts [50].

Type of conventional composite	References
Veneer and plywood	Mokhtar et al. [54] and Rosli et al. [55]
Compressed lumber	Choowang and Hiziroglu [56] and Choowang [57]
Sandwich panel	Srivaro et al. [58] and Srivaro [59]
Fiberboards	Onuorah [60] and Ramli et al. [53]
Particleboards	Sudin and Shaari [61] and Haslett [62]

Table 3. Conventional composite based on oil palm waste.

Biocomposites	References
EFB/polyester	Abdul Khalil et al. [63]
OPF/phenol formaldehyde	Sreekala et al. [64]
OPF/glycidyl methacrylate	Rozman et al. [65]
Oil palm fibers/rubber	Ismail et al. [66]
Oil palm wood flour/natural rubber	Ismail et al. [67]
EFB (carbon black)/epoxy	Abdul Khalil et al. [68]
EFB/polycaprolactone	Ibrahim et al. [69]
EFB/phenol formaldehyde	Chai et al. [70]
Short palm tree fibers-polyester	Kaddami et al. [71]
Short palm tree fibers-epoxy	Kaddami et al. [71]
Polyethylene modified with crude palm oil	Min et al. [72]
EFB fiber/poly(butylene adipate-*co*-terephthalate)	Siyamak et al. [73]
EFB fiber/polyethylene	Arif et al. [74]
EFB fiber/poly(vinyl chloride)	Abdul Khalil et al. [75]
OPT fiber/polypropylene	Abdul Khalil et al. [76]

Table 4. Thermoset based on biocomposite polymer and elastomer.

Utilization of natural fiber like oil palm empty fruit bunch (EFB) in polymer composites have some advantages such as low density, low cost, renewability, and biodegradability [51, 52]. The use of biomass from oil palm wastes has been demonstrated at the laboratory and pre-production levels as alternative raw wood materials for biocomposite production, for example particleboard, medium density fiberboard (MDF) and others [53]. These are the essential features and properties of fibers that are important and enable integration of oil palm biomass waste into existing industries for the purpose of product production.

4.1. Oil palm waste-based conventional composite

The biomass wastes include trunk, empty fruit bunch, leaf, mesocarp fiber, etc. are convertible into various biocomposite products. The type of conventional composite performance can be tailored to the end use of the product with each category classification is simple low and high density. Conventional composites are used in some structural and non-structural product applications, including panels for internal closure purposes to panels for outdoor use in furniture and multi-building support structures. Review on each potential biocomposite products can be manufactured from oil palm waste is presented in **Table 3**.

4.2. Oil palm waste-based polymer composites

This section provides an overview of use of oil palm waste fiber in the field of composite material. Bio-based polymers such as polylactic acid (PLA), polyhydroxybutyrate (PHB), cellulose ester, soy-based plastic, starch plastic, polymer trimethylene terephthalate (PTT), functional

Biocomposite	References
Polyethylene/tapioca starch/EFB biofilm	Roshafima and Wan Aizan [77]
Polypropylene/EFB	Rozman et al. [78]
High-density polyethylene composites/EFB	Mohd Ishak et al. [79]
High-density polyethylene composites/OPF/EFB	Rozman et al. [80]
Poly(vinyl chloride)/EFB	Bakar et al. [81]
Polyurethane/EFB	Rozman et al. [82]
Polypropylene/EFB-oil palm derived cellulose	Khalid et al. [83]

Table 5. Thermoplastic-based biocomposites polymer.

Hybrid composites	References
Oil palm fiber-glass fiber/epoxy	Jawaid and Abdul Khalil [84]
EFB-glass fiber/polypropylene	Rozman et al. [85]
EFB-glass fiber/polyester	Abdul Khalil et al. [26]
EFB bio-composites hybridized-kaolinite	Amin and Khairiah [86]
Oil palm fibers-glass fiber/polyester	Kumar et al. [87]
EFB-glass fiber/phenol formaldehyde	Sreekala et al. [64]
Sisal-oil palm fibers/natural rubber	Khanam et al. [88]
EFB-glass fiber/vinylester	Abdul Khalil et al. [89]
EFB-jute/epoxy	Jawaid et al. [90]

Table 6. Oil palm fiber-based hybrid composites.

vegetable oil-based resin and thermoset and elastomer biocomposites (**Table 4**) has revolutionized the plastic and petroleum world with biodegradable polymer.

Additionally, oil palm fiber can be used as a filler in thermoplastics and thermoset composites (**Table 5**). This composite has extensive applications in automotive furniture and components. In Malaysia, research and development in this area has finally reached commercialization levels to develop the thermoplastic composite, thermoset and elastomer composite for components used in the manufacture of proton cars [6]. In addition, hybrid composites also have lower modulus of storage than non-hybrid oil palm/PF composite composites. Research and production of various hybrid composites based on oil palm fiber are listed in **Table 6**.

5. Conversion of oil palm waste-based lignocellulosic to nanocellulose

Lignocellulosic of oil palm fibers such as hemicellulose, lignin and especially cellulose are also potentially exploited in nanotechnology. The pulp fiber from the oil palm fiber to produce a network structure unit such as nano-sized mesh called cellulose microfibril, it are obtained through mechanical treatment of pulp fibers which include smoothing process and high-pressure homogenizer process. The degree of fiber fibrillation of the pulp will increase the flexural flexibility of the fiber [75, 84]. This increase is due to the complete fibrillation of most fibers. The use of pulp (cellulose) as a reinforced booster with additional high pressure homogenization, composite strength will increase linearly against water resistance values and other properties [91].

In general, related materials such as hydrolyzed microcrystalline cellulose will rapidly clot when it is drained [92]. This, will complicate the next process. Therefore, surface modification should be carried out so that cellulose has compatibility with the matrix. Examples of applications for surface-made nanofibrillar celluloses are high-performance films and materials of nanocomposites, materials with superb hydrophobic surfaces as well as optical properties, electrical conductivity, magnetic or unique adsorption, new wood-based fibers with nanoscans or modified surface textures [93]. Products include filters, textiles, films, packaging materials, casting and mold components.

There are various methods had been reported for isolation of oil palm waste-based lignocellulosic to nanocellulose or nanoparticles, its can either in chemical treatment, mechanical treatment, and chemo-mechanical treatment processes [39, 94, 95] considered that alkali treatment seems to be effective in the removal of lignin and hemicelluloses components in palm oil EFB fiber. Mazlita et al. [96] suggested that chemical-sonication process were successfully generated from oil palm trunk (OPT) lignocellulosic biomass.

The characteristic of nanocellulose of oil palm wastes has great potential in applications such as strength enhancers polymer composites has been studied since the first half of the twentieth century. Nanocellulose extracted from oil palm biomass lignocellulosic can be classified in two main subcategories, nanofibrillated cellulose (NFC) and nanocrystalline cellulose (NCC). Research on the isolation nanofibres from oil palm biomass such as empty fruit bunch have

Event	References
Cellulose nanofibers were produced by hydrolyzing OPEFB with sulfuric acid	Fahma et al. [39]
Microfibrillated celluloses from OPEFB	Goh et al. [100]
Production defatted OPS nanoparticles	Dungani et al. [101] and Rosamah et al. [102]
Nanofibrillated from EFB using ultrasound assisted hydrolysis	Rosazley et al. [103]
EFB nanocrystalline cellulose was isolated from OPEFB microcrystalline cellulose	Rohaizu and Wanrosli [104]
Nanocellulose from OPF using alkaline processes	Mohaiyiddin et al. [105]
Production cellulose nanocrystals from OPF by hydrolysis treatment	Saurabh et al. [106]
Isolation of cellulose nanowhiskers from oil palm mesocarp fibers by acid hydrolysis and microfluidization	Adriana et al. [107]
Production cellulose nanocrystals from OPF by chemo-mechanical treatment	Nordin et al. [38]
Oil palm mesocarp fiber as a source for the production of cellulose nanocrystals	Chieng et al. [108]
Nanofillers obtained from OPA	Abdul Khalil et al. [7]
The utilization of OPA as a nanofiller for the development of polymer nanocomposites	Bhat and Abdul Khalil [109]
Nanocellulose was extracted from OPT fibers by a chemi-mechanical technique	Surip et al. [110]
Cellulose nanocrystals were isolated from OPT using acid hydrolysis method and total chlorine free method	Lamaming et al. [111]

Table 7. Events in the exploration of isolation nanocellulose from oil palm biomass with various methods and their related applications.

been conducted over the years [97]. It has been reported that cellulose nanofibers from cellulosic oil palm fiber can used as a reinforcing agent in composites materials. Meanwhile, research in the use of oil palm waste nanofiller such as oil palm shell and oil palm ash for manufacturing of wood composites have been carried out by Dungani et al. [98] and Sasthiryar et al. [99]. In general, the results of these studies indicate that, the addition of nanofiller can improve the properties of composites. The research development of isolation of nanocellulose of oil palm biomass and its related methods in various treatment are shown in **Table 7**.

6. Conclusion

The oil palm industry produces a high amount of waste during harvesting, replanting and processing at the plant. Generally, up to this day only 10% of the use of oil palm biomass residues is used as a biocomposite industrial raw material or as an alternative substitute material for wood raw materials. Oil palm waste that has lignocellulose content can be produce biomaterial as reinforcement in conventional biocomposite products (molded product panel, plywood, fiberboard, hybrid biocomposite, etc.) and advanced biocomposites (thermoplastics, thermosets and elastomers). Biomaterial can produce with or without treatment. That mean is the biomaterial from oil palm tree can be made from the fiber and isolated the cellulose content. Biomaterial from oil palm waste played an important role in the polymer composites and it can classified according to their origin. The types of biomaterial can be prepared from trunk, empty fruit bunch, frond, and shell. Reinforcement of biomaterials from different part of oil palm tree in thermoplastics and thermoset will give different characteristics. The different characteristic because of the physical and mechanical properties of oil palm fibers are mainly depended on their chemical content. The reinforcement oil palm waste into polymer composites have shown the sensitivity of certain mechanical and thermal properties to moisture absorption. These phenomena can be decreased by the employ fiber surface treatment.

In additions, biomaterial from oil palm waste reinforce in polymer composites could increase biodegradability, decrease environmental pollution, reduces cost and hazards. The waste disposal issue has directed most scientific research into eco-composite materials that can be readily degraded and assimilated by biological agent. The characterization of biomaterial reinforce in polymer matrix give some performance like, physical properties, chemical properties, mechanical composition, and also interaction between fiber as nanomaterial and matrix.

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Conflict of interest

The authors have declared that no competing interest exists.

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